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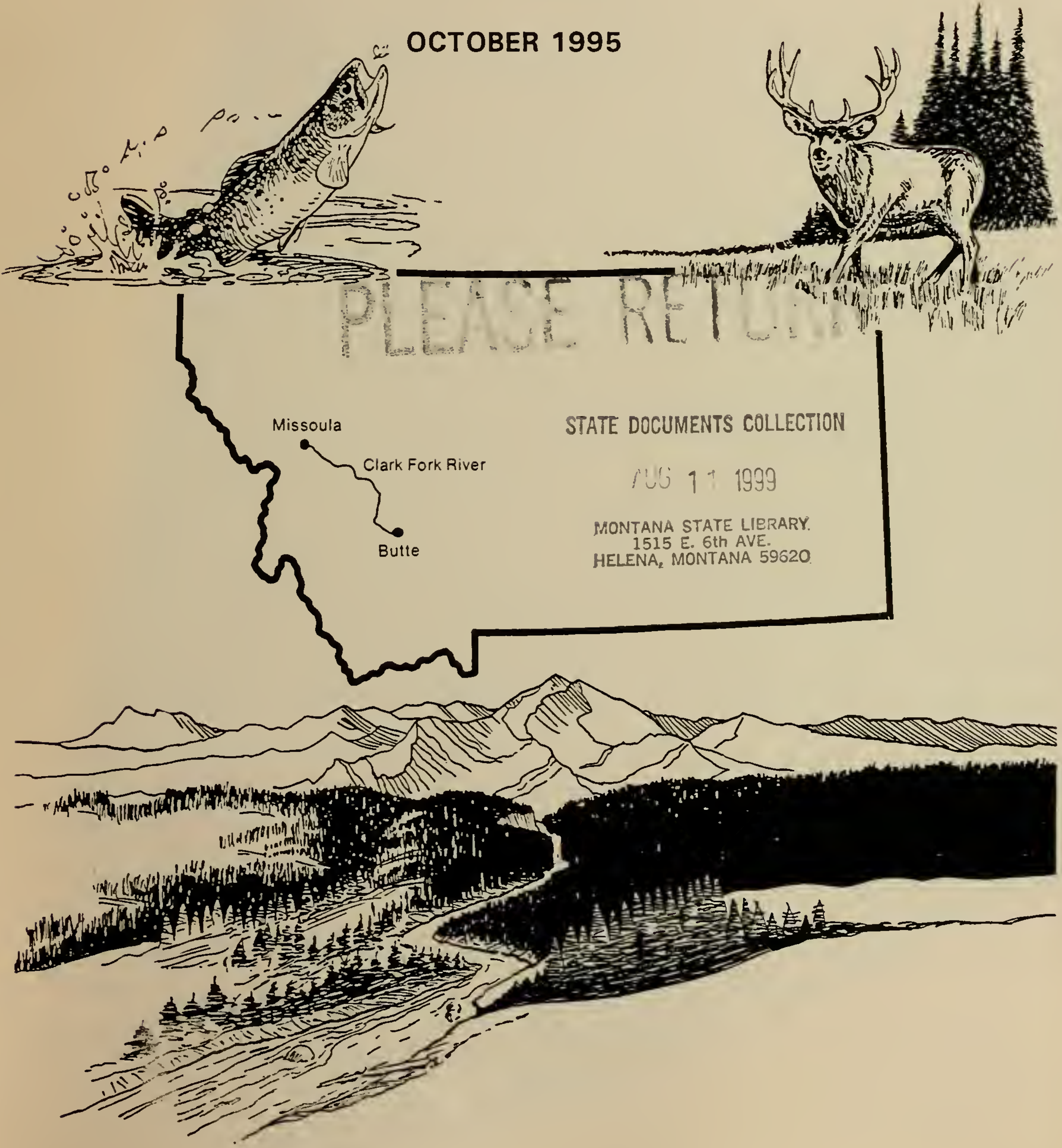
Revised report
and rebuttal

# STATE OF MONTANA
# RESOURCE DAMAGE PROGRAM

# REVISED REPORT AND REBUTTAL: ASSESSMENT OF DAMAGES TO GROUNDWATER AND LITERATURE REVIEW OF WATER USE VALUES IN THE UPPER CLARK FORK RIVER DRAINAGE

PREPARED BY:
JOHN W. DUFFIELD

OCTOBER 1995



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# REVISED REPORT AND REBUTTAL:

# ASSESSMENT OF DAMAGES TO GROUNDWATER AND LITERATURE REVIEW OF WATER USE VALUES IN THE UPPER CLARK FORK RIVER BASIN

STATE OF MONTANA
NATURAL RESOURCE DAMAGE LITIGATION PROGRAM

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OCTOBER 1995

# PREFACE

This revised report and rebuttal is submitted in response to: (1) "Volume IV - Critique of the State of Montana's Groundwater Valuation" by William DesVousges, July 13, 1995; and (2) "Volume V - Report on Potential Economic Losses Associated with Groundwater" by William DesVousges, July 13, 1995.

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## 1.0 SUMMARY

Groundwater resources in the Upper Clark Fork River Basin have been injured by releases of hazardous and deleterious substances as a consequence of mining and mineral processing operations in the Butte and Anaconda regions. This report provides a damage assessment for groundwater resources and a literature review of water use values in the Upper Clark Fork Basin. This damage assessment was developed in accordance with the natural resource damage assessment regulations for a Type B assessment promulgated by the U.S. Department of Interior (DOI) at 43 C.F.R. Part 11.

Natural resource damage assessments generally involve three related steps: injury determination, injury quantification and damage determination. This report relies on the State of Montana's groundwater injury reports (Maest et.al. 1995; Metesh 1993; Woessner 1995a, 1995b, and 1995c; and Duaime and Metesh, 1995) for injury determination and resource-based aspects of injury quantification. The basic findings of these reports is that aquifers in the Butte, Anaconda, Milltown, and Rocker area have been contaminated by releases of hazardous and deleterious substances. In the baseline condition all of these aquifers could supply water meeting drinking water quality standards. Natural recovery of these groundwater resources may be on the order of hundreds or even thousands of years. Specifically concerning the injured groundwater in the Butte Hill, bedrock and alluvial aquifers, and the Area I alluvial aquifer, the annual flux or yield is on the order of 13,600 ac-ft/yr. This is somewhat in excess of the total average annual Butte municipal system demand of 12,100 ac-ft/yr (Robert Peccia & Associates, 1991). Based on estimates by the Butte-Silver Bow GIS (Tully, 1995), there are some 3,467 residential properties and 376 business parcels over the contaminated aquifers. The total number of households utilizing the Butte municipal system is 9,923.

In a baseline condition, the groundwater resources on Butte Hill and in Area I could be used by residents as a source of tapwater through private wells. The Butte municipal water system could utilize this water through municipal wells. Because of the contamination in the Butte Hill and Area I aquifers, the services of this groundwater resource as a drinking water resource have been eliminated. Economic damages are computed by: 1) identifying the number of households that would have benefited from having access to the contaminated aquifer, 2) estimating the economic loss per household and 3) multiplying these two quantities together for each year 1981 into perpetuity. The economic loss per household is the sum of two quantities: 1) the extra cost of being connected to the existing Butte municipal water system compared to the cost of a private well or a municipal system based on groundwater and 2) the cost to households of boiling, purchasing, hauling or filtering to improve the quality of the Butte municipal system tapwater. Both of the costs are substantial because the existing Butte municipal system is one of the most expensive in the state.

This measure of economic loss is consistent with the DOI regulations. Compensable value for lost use of a resource is measured by "changes in consumer surplus, economic rent, and any

fees or other payments collectable by a Federal or State agency or Indian tribe" (43 C.F.R. § 11.83). The excess costs Butte residents pay for drinking water are a change in consumer surplus.

There are several ways to characterize the uses that would be made of the Butte Hill and Area I aquifers in the baseline state. In the baseline situation where aquifers are not contaminated, Butte groundwater would have been used for private wells and for a municipal water supply. Three baseline scenarios have been considered in this report that vary in terms of the typical extent of groundwater development that would have occurred in the baseline (Figure S.1). These scenarios are 1) extensive use of the currently contaminated Butte aquifers by private wells only, 2) a municipal system based entirely on groundwater serving at least the households located over the currently contaminated aquifers, and 3) a Butte municipal system based on both groundwater and surface water, wherein all households currently using municipal water in Butte face increased costs due to contamination of aquifers.

Total damages for the three alternative baseline scenarios are summarized in Table S.1. The most conservative estimate assumes that only private well users, not the municipal system, would in the baseline have utilized the currently contaminated groundwater sources. Based on an estimated 1790 affected households lying over the contaminated aquifers, total damages are $45 to $52 million, depending on the discount rate. The other two baseline scenarios examined arise from the likelihood that the Butte municipal system would also, in the absence of contamination, have used the currently contaminated aquifers. One such scenario conservatively assumes that only a limited municipal groundwater development would have occurred, sufficient to supply the households now lying over the contaminated aquifers. The estimate of these damages is $79 to $91 million, again depending on the discount rate. The final, and perhaps most likely baseline scenario, is that the primary water supplies for the entire Butte municipal system would have been the Butte area aquifers and Basin Creek. Under this scenario all 9,923 households currently connected to the Butte municipal system are worse off than if the currently contaminated groundwater had been used to supply municipal wells. Under this scenario, total losses are $187 to $217 million. In both of these latter scenarios, some portion of residents would have used private wells. However, since private well costs are even less than the estimated cost of a municipal system based on groundwater resources, not correcting for private wells makes the estimates for the latter scenarios more conservative.

An estimate was developed for the value of surface water used in irrigation in Silver Bow and Deer Lodge Counties. The dominant crops in these two areas are alfalfa and other hays. It is difficult to compute the value for other hays because of the common practice of grazing these crops directly after taking off one or more cuttings. For the two most common irrigation systems in these counties (wheel line and center pivot), the values of surface water in alfalfa based on a farm budget approach range from $8 to $34 per acre-foot depending on the assumed conveyance efficiency. For a wheel line sprinkler system on an alfalfa hay crop in

these counties, agricultural groundwater is valued at $14.39 per acre-foot. These estimates are similar to those reported in the literature (Gibbons 1986).

The Restoration Determination Plan for the Upper Clark Fork Basin (State of Montana, October, 1995) proposes to utilize substantial quantities of water for replacement of aquifer services (Alternative No. 2A) and to augment instream flows (Alternative No. 9A, 9B, and 9C). Since the basin is currently closed to new water rights, any new long-term use will need to purchase or lease rights from existing users. Most of the water use in the Upper Clark Fork Basin is in irrigation (87% of total acre-feet claimed) (Montana Department of Natural Resources and Conservation, 1988). Irrigation also is among the lowest valued water uses and is therefore the most likely source of any water rights transfers. Based on the experience in Southwestern United States water markets, prices for water transfers will be between the sellers reservation price (minimum the seller will accept) and the buyers willingness to pay. The buyers willingness to pay in this case is not obvious. If the seller is using water to irrigate alfalfa, the reservation price is the acre-foot values for surface water previously discussed. The experience of the Montana Department of Fish, Wildlife and Parks water leasing program is that it is difficult to obtain long term water rights leases from irrigators. One counteroffer the department has received that does not entail salvage water was for an annual lease rate of $70 per acre-foot. This was five times higher than the highest plausible reservation price for this particular right - $13 per acre-foot (Duffield et.al. 1991). It seems safe to say that long-term leases will not be available from irrigators at the reservation price.

Another possible source of water for restoration alternatives 2A and 9A, 9B, and 9C is the 13,138 acre-foot Silver Lake water supply in the headwaters of Warm Springs Creek. This resource was recommended to the Butte Water Company as the primary supply (along with the Basin Creek Reservoir) for meeting Butte's water supply needs in the Montgomery (1988) Butte Water System Master Plan. A lease agreement, in memorandum form, was reached in 1987 between Dennis Washington and the Butte Water Company that would have produced 11 million gallons per day (or 17 cfs). The annual cost over a proposed ten year lease term was reported to be $69 per acre-foot, with the option of a second ten year renewal. This water source was also mentioned in connection with a bid to Micron Technology Inc. to locate a manufacturing plant near Butte (Hieger, 1995). No specific prices were mentioned in connection with the Silver Lake supply in this instance.

To conclude, there is considerable uncertainty in predicting prices for long-term water rights transfers in the Upper Clark Fork Basin. Reservation prices for water rights transferred from irrigated agriculture could be as low as $8 to $34 per acre-foot depending on the irrigation system. But it seems unlikely that ranchers would lease at the value of their marginal product. The only offers for substantial water rights transfers to nonirrigation uses that were identified in the area are both for around $70 per acre-foot, and these were made some years ago. It is likely that prices on the order of $40 to $50 an acre-foot or more may be necessary to secure rights of the magnitude and term described in the restoration report.

This report also provides a review of the literature on the values associated with marginal changes in municipal water supply, as in the case of water shortages. These values are on the order of $1000 per acre-foot.

**Table S.1. Estimated Total Damages to Residential Water Users Due to Groundwater Contamination**

| Estimate | Based on Desvousges and Waters (1995) year specific real cost of capital | Based on 7% real cost of capital |
|---|---|---|
| Estimated losses based on lost access to private wells | $51,886,259 | $44,530,297 |
| Estimated losses based lost access to a groundwater municipal system in the contaminated area | $90,881,592 | $79,161,383 |
| Estimated losses based on lost access to a partially groundwater based municipal system | $216,990,511 | $186,979,204 |

**Figure S.1 Baseline Service Scenarios for Butte Groundwater**

| Key Parameters/ Characteristics | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| Groundwater[1] utilized by: | Private wells | Limited municipal wells | Extensive[2] municipal wells |
| Potentially affected household | Households located over contaminated aquifers (3,467) | Households located over contaminated aquifers (3,467) | All households connected to municipal system (9,923) |
| Affected populations | Share who would prefer to be on private well (1,790) | Share utilizing groundwater system (3,467) | Share utilizing groundwater system (9,923) |
| Lost use value | Municipal cost plus averting cost minus well cost | Municipal costs for existing system plus averting costs minus municipal costs with groundwater supply | |

[1] Includes Butte Hill bedrock aquifer, and Butte Hill, Area I and valley alluvial aquifer.

[2] Combined Butte Area groundwater resources and Basin Creek.

## 2.0 INTRODUCTION

This report provides an assessment of damages to groundwater resources and estimates of unit (per acre foot) values for municipal and agricultural uses of groundwater in the upper Clark Fork River and Silver Bow Creek Drainages.

A description of the groundwater contamination at issue is provided in the State of Montana groundwater injury assessment reports (Maest et.al. 1995; Metesh 1993; Woessner 1995a, 1995b, and 1995c; and Duaime and Metesh, 1995). Aquifers under and in the near vicinity of Butte, Anaconda, and Milltown have suffered contamination which has rendered some groundwater unusable as municipal or private residential water sources.

This report is organized as follows. The next several sections provide an assessment of damages to Butte groundwater resources. This assessment is consistent with the guidelines in the U.S. Department of Interior (DOI) natural resource damage regulations (43 C.F.R. Part 11). The remaining sections of this report address the value of surface water and groundwater resources when used for agricultural or municipal purposes in the Upper Clark Fork Basin. These values are based on analysis and a review of the literature.

There are a number of alternative approaches to valuing changes in the supply or availability of groundwater for municipal uses. These include: 1) marginal values derived from existing models of residential water demand, 2) market prices for water transactions, 3) cost savings over alternative sources. For agricultural uses the primary approach is to examine the contribution of groundwater to agricultural production (the factor price approach). These methods are consistent with the DOI regulation guidelines for measuring compensable values and are utilized in this report.

## 3.0 ASSESSMENT OF DAMAGES TO GROUNDWATER

Often when groundwater contamination occurs in an area a substitute source of water supply will be used - such as a surface resource or groundwater from an uncontaminated aquifer. In this case there may be an economic loss if the cost of using the groundwater in its uncontaminated state is lower than the cost of the substitute resource.

Figure 3-1 (the area bounded by P1, A, B and P2) provides a graphical measure of the possible cost savings of a water resource available at price P2 compared to the existing price P1. There is also a loss associated with the foregone consumer surplus associated with the increased use from Q1 to Q2 ( the area bounded by A, B, and C).

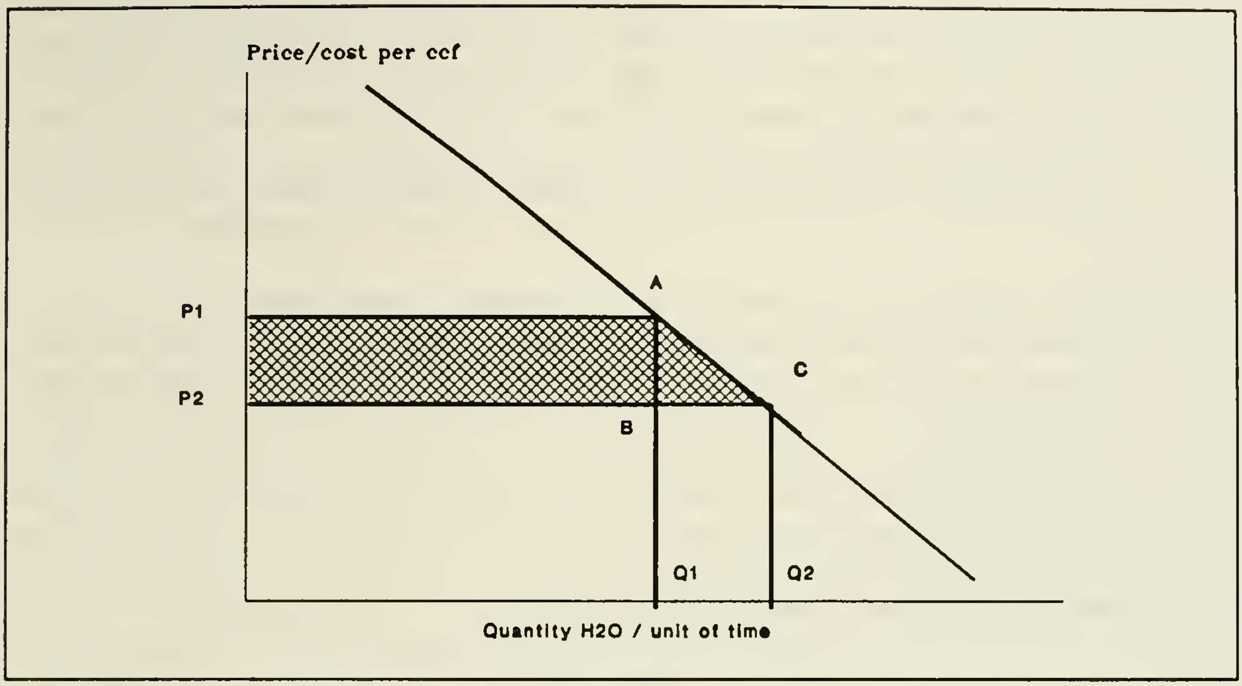


Figure 3.1. Graphical area representing the economic loss associated with using a resource available at average cost of P1 compared to P2.

There are several ways that contamination of an aquifer can lead to increased water supply costs for households and businesses: 1) due to the presence of a contaminated aquifer, individuals may connect to a more expensive municipal system rather than use individual groundwater wells, and 2) a contaminated local aquifer may force a municipality to use other more expensive surface or groundwater resources. In addition to high or increased water bills compared to well costs, the water quality from the substitute source may be worse than from an uncontaminated well. In this case, households and businesses may incur additional costs of improving their tapwater such as boiling, hauling water from elsewhere, purchasing bottled water or installing filters. These costs of "averting" or improving the low quality municipal water are in addition to the costs of being on a more expensive municipal system.

To estimate total groundwater-related damages two types of information are needed: 1) the total number of households or businesses affected and 2) the increased cost per household or business of using the substitute resource. Total increased costs per household are represented by the rectangle P1, P2, A, B in Figure 3-1. Point P1 represents the combined costs of higher municipal bills and averting costs (purchasing bottled water, etc.) and Point P2 represents the costs the household would face for water supply if the aquifer was uncontaminated - the so-called baseline case. P2 is lower than P1 if being on private wells is cheaper than municipal rates or if a municipal system using the uncontaminated aquifer would have lower rates than the existing system. The analysis described below is conservative in that consumer surplus loss from reduced water consumption at higher prices (triangle ABC in Figure 3-1) is not quantified.

Total groundwater-related damages are equal to the increased cost of the substitute source per household or business times the number of households and businesses affected. Damages are computed for each year lost use occurs from 1981 until the resource is fully recovered. In the case of groundwater resources, the injury will likely be present into perpetuity. The following sections outline these computations. The use and value derived from the aquifer in a contaminated and uncontaminated (or baseline) state are compared for each year. The estimates are conservative as losses to the use of tapwater by businesses are not quantified.

In the baseline situation where aquifers are not contaminated, Butte groundwater would have been used for private wells and for a municipal water supply. Three baseline scenarios have been considered in this report that vary in terms of the typical extent of groundwater development that would have occurred in the baseline. These scenarios are 1) extensive use of the currently contaminated Butte aquifers by private wells only - no municipal use of groundwater (1,790 affected households), 2) a municipal system based entirely on groundwater serving at least the households located over the currently contaminated aquifers - about 3,467 affected households, and 3) a Butte municipal system based on both groundwater and surface water, wherein all households currently using municipal water in Butte, (9,923 households), face increased costs due to contamination of aquifers (see Figure S.1).

In the first case examined below, households are assumed to use private wells in the baseline. In the second and third cases, the baseline is one in which households benefit from a groundwater-based municipal system.

### 3.1 Lost Use of Private Wells Due to Contaminated Groundwater

As noted, there are two potential categories of loss that are associated with the use of substitute sources of water. First, as was described above, is the cost associated with purchasing a more costly alternative to the contaminated groundwater. The second category of loss occurs if the substitute source of water is of a lower quality than the groundwater would have been in the absence of contamination. These averting costs include the costs which individuals incur in an attempt to bring the substitute water source up to the same level of quality which would have been found in groundwater in the absence of contamination. Both of these categories of loss apply to many households currently using the Butte municipal water system.

The Butte municipal water system has experienced significant problems with the quality of its water in recent years. In a recent survey of Butte residents, 85.8 percent of respondents said that they were aware of serious problems with the quality of the water they used in their homes (Desvousges, 1995b). Table 3.1 details the percentages of respondents to this survey who indicated they had experienced specific water quality problems in their homes.

**Table 3.1. Percent of Survey Respondents Experiencing Problems with Butte Municipal Water.**

| Problem | Percent of Respondents |
|---|---|
| Aware of serious problems with the quality of water used in home | 85.8% |
| Water is dirty or discolored | 73.4% |
| Water tastes bad | 57.2% |
| Water smells | 59.5% |
| Water is unsafe for drinking or food preparation | 58.0% |
| There are boil water orders | 64.6% |
| There is too much chlorine in the water | 56.2% |

Source: Montana Water Quality Survey, Desvousges, 1995b.

The following analysis quantifies the two categories of losses suffered by residents of Butte who would prefer to be on uncontaminated private wells rather than be connected to the existing Butte water system. First the increased cost associated with purchasing water from the Butte municipal system are computed and second, the cost of "averting behaviors" incurred in order to improve the quality of or augment the municipal water source are computed.

### 3.1.1 Extent of Groundwater Contamination and Number of Affected Residences

Determination of the extent of economic loss associated with mine-related groundwater contamination depends fundamentally upon the spatial extent of groundwater contamination. Maest et al. (1995), Duaime and Metesh (1995), and Metesh (1995) report that the services of two Butte aquifers are affected by mine-related contamination. These contaminated areas are shown in Appendix A and lie beneath some 3,467 residences (Tom Tully, Butte-Silver Bow GIS, see Appendix A). These residences represent those Butte water users with the potential for having suffered losses due to foregone use of actual or potential wells located over groundwater contamination.

### 3.1.2 Estimated number of water users incurring losses due to unavailability of groundwater resources

Of the 3,467 some residences that are located over the area of groundwater contamination in Butte, a certain percentage will have suffered economic losses due to the unavailability of groundwater as a potential residential water source. These affected water users are those who,

in the absence of contamination, would have liked to use groundwater as a water source for their residence.

In a recent survey of Butte residences over or in close proximity to the contaminated alluvial aquifer respondents were asked the question: "Suppose that your household had a choice between a well and the public water supply. If the quality of water was equally good from both sources and **all other factors**, including costs and taste, **were the same**, would your household rather use a well or the public water supply?" (emphasis in the original) In responding to this question 33.6 percent of the 339 individuals asked said they would rather be on a private well (Triangle Economic Research, 1995, Final data set, Montana Water Quality Survey, which was used to prepare Desvousges, 1995b). This 33.6 percent represents a lower bound of the number of potentially affected residences over the contaminated areas. In fact, in the absence of groundwater contamination neither the costs nor the qualities would be the same between groundwater and the Butte municipal water. As is discussed in the following sections, the long run cost of groundwater in the Butte area is significantly lower than municipal water cost. Additionally, as is shown in the responses detailed in Table 3.1, the quality of municipal water in Butte is significantly worse than what could be expected from an uncontaminated groundwater well.

In order to estimate the percentage of residences who, in the absence of contamination, would prefer to rely on a private well for their residential water needs, a second survey of Butte households was conducted. This telephone survey, which was implemented by Responsive Management of Harrisonburg, Virginia in conjunction with Bioeconomics, Inc., reworded the question above to reflect the realities facing Butte water users. This survey asked respondents: "Suppose your household had a choice between being on a private well or the Butte municipal water system for your tap water. Say the water from the private well would be of better quality, as well as less expensive in the long run than the Butte water system. Which system would your household prefer, given these conditions?". Responding to this question, 54.89% of homeowners indicated they would rather be on a private water well. Attachment B.5 provides a listing of reasons individuals gave for their preference. Many individuals mentioned that uncontaminated well water would be of better quality. Additionally 39.53% of landlords said they would like their rental properties to be on a private well under these conditions. The survey found that 21.22% of respondents were renters and 78.78% were homeowners. The estimated weighted percentage of residents who in the absence of contamination would prefer to receive their water from a private well is therefore 51.63% of households in the affected area. This percentage corresponds to 1,790 residences. See Appendix B for a discussion of the phone survey implementation and results.

### 3.1.3 Estimated loss per household associated with use of municipal water rather than a private groundwater well

Those residences who, in the absence of contamination, would have drilled private wells suffer losses equal to the amount which the cost of municipal water service exceeds the cost of water from a private well. Desvousges (1995b) estimated that residential Butte water users pay an average of $533.16 per year in municipal water costs. An examination of the current water rates

for Butte Water Company shows that the flat rate charges for a 5-6 room house with 2 baths and a laundry are $32.43 per month or $389.16 per year. Adding to this $144.48 in fees for sprinkling a 3,000 square foot residential lot yields an annual cost of $533.64. This figure is very similar to the survey based estimate supplied by Desvousges. In the following analyses we use Desvousges' estimate of $533.16 per year for residential municipal water costs.

Table 3.2 shows the calculation of the average annual costs of water from a well drilled in the contaminated aquifer. The estimates in Table 3.2 assume an average well depth in the weathered bedrock of 200 feet. This is conservative compared to the sample of 174 wells in bedrock south of Butte (Duaime and Metesh, 1995). Additionally, Table 3.2 assumes a 1.5 horsepower, 18 gallon per minute pump. Cost estimates were supplied through personal communication with O'Keefe Well Drilling, Butte, Montana. Table 3.2 shows that the estimated annual cost of private well water is $270.72. This estimate is slightly higher than well costs estimated by Desvousges (1995b) ($213 to $222 per year per residence) reflecting the higher cost of drilling deeper in the bedrock aquifer as opposed to the alluvial aquifer examined by Desvousges (1995b).

**Table 3.2. Estimated Annual Well Costs.**

| **Well Cost Component** | **Total Cost** | **Annual Cost** |
|---|---|---|
| Well drilling and caseing[a] | $3,835.00 | $123.10 |
| Pump[b] | $800.00 | $80.00 |
| Piping, electrical, and ditch[a] | $1,200.00 | $38.52 |
| Pressure Tank[a] | $385.00 | $12.36 |
| Electrical operating cost[c] | -- | $16.74 |
| Total Annual Cost | -- | $270.72 |

[a] Well drilling cost based on a 200 feet at $19 per foot, plus $35 for drive shoe. Drilling, piping, electrical, ditch, and pressure tank are annualized using a 1994 real cost of capital of 3.21%. Source for real cost of capital is Desvousges and Waters (1995), Appendix D.

[b] Pump costs amortized over an estimated 10 year life.

[c] Annual Electricity cost based on a 1.5 horsepower pump pumping 15 gallons per minute and 0.688 acre feet per year.

Based on the estimated annual costs per household for Butte municipal and private well water, the cost per household per year of using municipal rather than private well water in Butte is estimated to be $262.44. This estimate of loss is conservative because a percentage of the private wells would be in the alluvial aquifer which would require shallower, and thus, cheaper wells.

### 3.1.4 Estimation of annual averting costs for Butte households

The second category of loss suffered by Butte households as a result of contaminated groundwater includes the costs of averting actions which the households take in an effort to improve the quality of the water they receive from the Butte municipal water system. These actions can include installing filtration systems, buying bottled water, hauling water from another source, or other actions. Desvousges (1995) implemented a household survey within a portion of the affected area and in a comparison area which asked respondents detailed questions about any averting actions they have taken and costs which they have incurred. Desvousges estimated that Butte residents living over contaminated portions of the alluvial aquifer incur between $348 and $666 in annual averting costs. The range in these estimates is based on different treatments of joint costs. Joint costs arise, for example, when other stops are made on a trip to haul water. The share of the trip costs that should be allocated to hauling water is not obvious. The estimate of $348 per year does not include the opportunity cost of time whenever the respondent took multipurpose trips to buy bottled water or haul water. The estimate of $666 per year includes the opportunity cost of time for all trips to buy or haul water. The general categories of averting cost loss measured by Desvousges were buying bottled water, hauling water from another source, boiling water, filtering water, and changing purchasing behavior. Devousges also noted that based on his survey findings there was no statistical difference between the averting costs incurred by individuals living outside the area of contamination and by those over the contamination. In calculating our estimate of annual averting costs we included all the households in Desvousges' survey. We have also adjusted the estimates derived by Desvousges by correcting for an apparent error in the dataset. We corrected what appears to be a typographic error in the length of time it took respondent ID # 10360 to drive 35 miles one-way in order to haul water from another source. Desvousges' spreadsheets showed this household spending 45.58 hours one way, or 91.16 hours per round trip of 70 miles. This entry was changed to 0.58 hours per one way trip. This correction significantly lowers the high-end estimated average costs of averting behavior from the $666 used by Desvousges to $540.62 per year.

Table 3.3 shows the newly estimated annual averting costs by activity. This table shows that our calculation of total annual averting costs per household range from a low of $336.19 to a high of $540.62. Based upon Desvousges' data corrected as above, our average estimated annual averting costs are $438.41. This annual averting cost is used in our damage estimates. (Note that Desvousges used an average averting cost in his study of $507.)

This estimate of annual averting costs is conservative in two respects:

1) Desvousges calculated out-of-pocket costs of driving to buy bottled water or to haul water from another source by simply calculating the cost of gasoline used. This method significantly understates the costs associated with operating a vehicle. Abdalla (1990) suggested using an average operators cost per mile of 32.6 cents based on American Motor Vehicle Manufacturers Association estimates for 1988. Additionally, the 1995 mileage rate allowed by the Internal Revenue Service is 30 cents per mile.

2) Desvousges did not calculate any opportunity cost of time associated with boiling water in the home. Abdalla (1990) assumed that 1/4 of total boiling time was unavailable for other productive use.

Excluding the full cost of vehicle operation and a reasonable measure of opportunity cost of time associated with boiling of water results in a very conservative estimate of the annual averting costs incurred by Butte residents. Including these additional costs would result in a much higher average annual averting cost of $622.76 per household.

**Table 3.3. Estimated Annual Averting Expenditures.**

| Averting Activity | Low Cost Estimate | High Cost Estimate |
|---|---|---|
| Buying Bottled Water | $147.97 | $217.45 |
| Boiling Water | $4.74 | $4.74 |
| Hauling Water | $120.98 | $255.93 |
| Filtering Water | $8.15 | $8.15 |
| Changing Purchases | $53.39 | $53.39 |
| Other Activities | $0.96 | $0.96 |
| Total Averting Costs | $336.19 | $540.62 |
| Average of Low and High Averting Costs | $438.41 | |

Source: Desvousges (1995b) corrected.

In recent years improvements have been made to the Butte municipal water system. These improvements make it likely that many averting actions taken by households will cease once the households become convinced that water quality has been permanently improved. Desvousges in his calculation of averting costs assumed that all averting behaviors would cease after 1997. A certain percentage of averting behaviors will continue into perpetuity due to investments in equipment such as filtration systems, continued distrust of the municipal system, or continued dissatisfaction with municipal water quality such as the level of chlorination. The assumption that some averting behavior will continue on into perpetuity is supported by responses to certain questions in the Montana Water Quality Survey. Respondents to this survey were asked whether they would continue their averting actions even if water quality problems were corrected. Table 3.4 shows the percentage of respondents that indicated they would to some degree continue their averting behaviors.

**Table 3.4. Percentage of Respondents to Montana Water Quality Survey Who Would Continue Averting Actions.**

| Averting behavior | Percentage of Respondents |
|---|---|
| Buying bottled water | 24.7% |
| Boiling water | 11.3% |
| Hauling water from another source | 21.8% |
| Using a water filter | 57.8% |
| Changing purchasing habits | 39.2% |

Source: Desvousges (1995b) Montana Water Quality Survey

When the percentages of households who would continue averting behaviors, shown above, are applied to the average annual averting expenditures shown in Table 3.3 the result is an estimated future annual average averting cost per affected household of $112.39. We compute damages based on averting costs dropping to this level in 1998 and continuing at this level into the future.

### 3.1.5 Estimation of total economic losses to Butte households due to groundwater contamination.

In the preceding sections we have detailed the estimation of the components necessary for calculation of total economic losses to Butte households due to contaminated groundwater. These components are average annual municipal water costs, average annual private well water costs, average annual averting costs, number of households in the affected area, and the percentage of households in the affected area suffering damages.

Following the methodology of Desvousges (1995b), we calculate the total losses for affected households based on 1994 cost estimates and apply present net worth factors to this annual loss for the periods 1981-1997 and 1998 to perpetuity. Table 3.5 shows the calculation of total annual economic losses to Butte residences and Table 3.6 shows the calculation of the net present value of total past and future losses to residential Butte water users. The estimates are for present net value as of 1996 and in 1995 dollars. Butte municipal costs are in 1994 dollars in the absence of more recent information (although municipal water rates have not risen in Butte since 1994); averting and well costs are in 1995 dollars as averting are based on a 1995 survey and well costs are based on 1995 price quotes.

**Table 3.5. Total Estimated Past and Future Residential Losses Due to Groundwater Contamination.**

| Years | Municipal cost (M) | Well cost (W) | M - W | Averting costs (A) | M-W+A | (M-W+A) * 1790 |
|---|---|---|---|---|---|---|
| 1981-1997 | $533.16 | $270.72 | $262.44 | $438.41 | $700.84 | $1,254,517 |
| 1998 - Perpetuity | $533.16 | $270.72 | $262.44 | $112.39 | $374.83 | $670,942 |

**Table 3.6. Calculation of present net value of past and future losses to residential water users.**

| Statistic | Based on Desvousges and Waters (1995) year specific real cost of capital[a] | Based on 7% real cost of capital |
|---|---|---|
| PNW factor for 1981-1997 | 24.496068 | 28.822633 |
| PNW factor for 1998-perpetuity | 31.531069 | 12.477696 |
| Estimated 1981-1997 losses | $30,730,734 | $36,158,484 |
| Estimated 1998 to perpetuity losses | $21,155,525 | $8,371,813 |
| **Total estimated losses to residential households** | **$51,886,259** | **$44,530,297** |

[a] see Desvousges and Waters (1995) Appendix D, for a discussion of calculation of discount rates.

This estimate for total losses to water users in Butte of 45 to 52 million dollars is conservative in several respects.

1) The estimates consider only losses due to increases in costs to water users. They do not consider the losses in consumers' surplus associated with these increased costs. ( Figure 3.1)

2) The estimates do not include any losses for residences located near but not over contaminated portions of the aquifers. These water users may have opted not to install

private wells because of uncertainty as to the exact extent of the area of contamination. In fact a significant number of residences are located in a narrow band lying between the contaminated bedrock and alluvial aquifers.

3) The estimates do not include losses to governmental and public properties and buildings located over the contaminated aquifers. These properties include parks and athletic fields and these buildings include schools, hospitals, museums, and courthouses.

4) The estimates do not consider the additional losses of households who have an installed well they are unable to use due to groundwater contamination.

5) The estimates assume that all private wells would be drilled in the bedrock aquifer. In fact, a portion would be drilled in the alluvial aquifer. These wells in the alluvial aquifer would be shallower and thus cheaper than those installed in the bedrock.

6) The estimates include no damages for the estimated 376 businesses which are located over the areas of contamination. These businesses also face certain averting costs such as the purchase of bottled water for employees and/or customers.

7) The averting cost estimates are based on Desvousges (1995b). It is possible that the Desvousges survey understated the extent of averting behavior.

8) Using the full costs of operating an automobile and some allowance for the opportunity cost of time in boiling water would result in averting costs that are 40% higher than those used here.

### 3.2 Lost municipal use to residents living over contaminated groundwater

Survey responses demonstrate that a large percentage of residents in the affected area would, in the absence of groundwater contamination, rather have a private well than subscribe to the Butte municipal water system. It is also true, however, that the municipal system itself has been deprived of the opportunity to develop groundwater in the contaminated area, and thus it has been forced to rely on surface water resources for its municipal water supply.

An alternative estimate of losses to residences located over the contaminated portions of the aquifer can be calculated under the assumption that a municipal system using Butte Hill groundwater as a supply could, in the absence of contamination, have been developed for the water users in the affected area. It is plausible that if the Butte Hill and Area I groundwater resources were in a baseline uncontaminated condition, they would have been used for a Butte municipal water supply (John Metesh, personal communication). A large share of Montana public water systems utilize groundwater resources (MT DHES, 1994). In this section, a very conservative scenario is described in which a groundwater-based municipal system would only serve households in the part of Butte over the currently contaminated aquifers. An alternative baseline scenario, in which municipal groundwater resources are utilized at least in part by the municipal system city-wide is presented in the following section (Section 3.3).

The flux of the contaminated aquifers is estimated to be 13,600 acre feet per year or 12 million gallons per day (Maest et al., 1995). This is a conservative estimate of the possible yield of these aquifers if developed for municipal groundwater uses (pers. comm., John Metesh). This resource is more than adequate to supply the current number of households and businesses over the contaminated aquifer, which would have a total average annual demand equal to about 2,600 af per year. In the absence of mining it is likely that the Butte municipal system would have been based on local groundwater wells rather than pumping a large share of the water supply 20 miles from the Big Hole River, over the Continental Divide, to Butte.

Under the liberal water use assumption of 25 ccf per month for each of the 3,843 residences and businesses located over the contaminated groundwater, total annual use would be 2,644 acre feet, or 1,639 gallons per minute. Applying a multiple of three to this amount to allow for maximum demand days (James B. Montgomery, Inc., 1987) results in a required flow of 4,917 gallons per minute capacity. This assumes that maximum demand is not in part met by storage. Well logs from the bedrock aquifer in the residential development south of Butte show the average capacity of 174 wells at 18.8 gallons per minute (Duaime and Metesh, 1995). This implies that 262 typical residential wells would need to be installed in the bedrock aquifer to supply a municipal system to the area. This is not a large number of wells by comparison, for example, with the number of monitoring wells just in Area I (pers. comm. John Metesh). Alternatively, a lesser number of wells could have been installed in the alluvial aquifer along Silver Bow Creek; as few as 50 pumping 50 gallons per minute, could be adequate in conjunction with a storage system (pers. comm., John Metesh).

### 3.2.1 Estimated cost per year of a Butte groundwater-based municipal system.

There are many small to medium sized towns in Montana utilizing groundwater as their sole municipal water supply (Table 3.7). An informal survey of groundwater based medium to large municipal systems in Montana found that the average price per hundred cubic feet (ccf) of water (weighted by the number of municipal hookups in each community) is currently approximately $1.18. (The surveyed Montana municipal systems on 100% groundwater used in this calculation were Livingston, Missoula, Anaconda, Kalispell, and Deer Lodge.) In comparison, the cost under the assumption of 25 ccf per month usage for private well groundwater in Butte, estimated in Section 3.1.3, is $0.9024 per ccf. The average ccf rate for groundwater municipal systems of $1.18 is approximately one-half the current Butte municipal rate per ccf for a metered customer using 25 ccf per month ($2.3576 per ccf). In order to be conservative the highest rate observed per ccf for a groundwater based system (that of Anaconda at $1.416 per ccf) was used to calculate the Butte municipal charge under the assumption of a groundwater based system. The $1.416 per ccf for Anaconda (Table 3.7), is the equivalent of $320.22 per year. For purposes of this baseline scenario, we do not specifically estimate the number of private wells in the area of contamination. This makes the damage estimate more conservative. It is possible that there would be few private wells in the area of contamination in the baseline since a groundwater-based municipal system would be substantially cheaper and would have much higher quality water than under the current and historical surface water system. The use of the Anaconda municipal groundwater based rate of $320.22 per year for residential water users provides a conservative

estimate of damages over the alternative assumption that some percentage of water users would still prefer to have a marginally cheaper private well system.

**Table 3.7. Montana municipal water rates and groundwater dependence.**

| Municipality | Predominantly groundwater | | Predominantly surface water | |
|---|---|---|---|---|
| | Rate per ccf[a] | % groundwater | Rate per ccf | % groundwater |
| Missoula | $1.24 | 100% | -- | -- |
| Kalispell | $0.965 | 100% | -- | -- |
| Livingston | $1.30 | 100% | -- | -- |
| Anaconda | $1.416 | 100% | -- | -- |
| Deer Lodge | $0.448 | 100% | -- | -- |
| Butte | -- | -- | $2.358 | 0% |
| Cutbank | -- | -- | $1.77 | 0% |
| Glendive | -- | -- | $1.228 | 0% |
| Havre | -- | -- | $1.122 | 0% |
| Great Falls | -- | -- | $0.8328 | 0% |
| Helena | -- | -- | $1.82 | ~10% |
| Billings | -- | -- | $1.046 | 0% |

[a] Based on 25 ccf per month consumption and 1994 metered rates.

Based on an estimated annual cost of $320.22 per year for residential users on a groundwater municipal system in the affected area, the cost differential between current municipal rates ($533.16 per year) and estimated baseline rates is $212.94 per year per residential household.

In addition to losses due to unavailability of groundwater for municipal use, residences in the affected area also suffer losses due to the averting expenditures they make in order to improve the quality of their water. These annual averting expenditures are the same as were calculated in Tables 3.3-3.5.

### 3.2.2 Economic damages for lost municipal use of Butte groundwater

Based on the previously described cost estimates per household and the number of households over the contaminated aquifers (3,467), estimated annual costs of lost municipal use are computed in Table 3.8. Table 3.9 computes the present net worth of these losses in 1996.

| Table 3.8. Total Estimated Annual Past and Future Residential Losses to 3,467 Households Located Over the Area of Contamination | | | | |
|---|---|---|---|---|
| Years | Municipal cost (M) | Groundwater Municipal cost (M2) | Averting costs (A) | (M-M2+A) * 3467 |
| 1981-1997 | $533.16 | $320.22[a] | $438.41 | $2,258,213 |
| 1998 - Perpetuity | $533.16 | $320.22 | $112.39 | $1,127,911 |

[a] calculated as ($1.416/$2.3576)*533.16=320.22

| Table 3.9. Calculation of present net value of past and future losses to 3,476 residential water users located over areas of contamination. | | |
|---|---|---|
| Statistic | Based on Desvousges and Waters (1995) year specific real cost of capital | Based on 7% real cost of capital |
| PNW factor for 1981-1997 | 24.496068 | 28.822633 |
| PNW factor for 1998-perpetuity | 31.531069 | 12.477696 |
| Estimated 1981-1997 losses | $55,317,342 | $65,087,648 |
| Estimated 1998 to perpetuity losses | $35,564,250 | $14,073,735 |
| **Total estimated losses to residential households** | **$90,881,592** | **$79,161,383** |

For the baseline case where the municipal water system uses groundwater to serve households living over the currently contaminated aquifer, the estimate for total losses to water users in Butte is between 79 and 91 million. This is a very conservative estimate of losses. Excluded from the analysis are the remainder of residential and commercial water users in Butte not located over

contaminated portions of the aquifer. It appears that in the absence of contamination, groundwater resources underlying Butte would have a yield greater than the average current water demand for the entire Butte municipal water system. (Peccia ( 1991) reports a total average annual demand of 10.8 mgd or 12,120 ac. ft. per year.) A complete accounting of losses due to contamination, therefore, would include increased municipal water costs and averting expenditure costs to all municipal water users within Butte, not just to those located over the contaminated portion of the alluvium. Inclusion of only water users located over contamination therefore provides a very conservative estimate of total damages.

## 3.3 Lost Butte city-wide municipal use due to contaminated groundwater.

This section provides an estimate of the lost use value due to contaminated groundwater in Butte for a baseline scenario that evaluates losses to all 9,923 households now using the Butte municipal system. The next subsection provides a summary comparison of alternative groundwater and surface water supply sources in the Butte area.

### 3.3.1 Baseline water supply sources in the Butte area

For the baseline situation, where none of the Butte aquifers are contaminated, plausible sources for the Butte municipal water system would include the Butte Hill bedrock and alluvial aquifers and the alluvial aquifer in the flats including Area I (John Metesh, personal communication). In addition, the most proximate, clean and least expensive to develop of the Butte area surface water resources may also have been developed in the baseline - possibly including the existing Moulton and Basin Creek reservoirs as well as Upper Silver Bow Creek. These sources are summarized in Table 3.10.

The flux of the contaminated aquifers has been estimated to be 13,600 acre feet per year or 12 million gallons per day (mgd) (Maest et.al. 1995). This is a conservative estimate of the possible yield of these aquifers if developed for municipal groundwater uses (John Metesh, personal communication). A technically feasible configuration of wells for the bedrock aquifer is discussed in John Metesh's deposition (at pages 528-532). Also Duaime and Metesh, 1995 at p. 10 note: "There are many examples of the actual and potential productive nature of the bedrock aquifer in the Butte area. Records of the drainage and pumping rates of the mines and recent development of the bedrock aquifer outside the influence of mining indicate a viable and productive aquifer." An estimate of the yield and depth of wells in essentially the same bedrock aquifer is based on 174 wells in the residential development just south of Butte including Terra Verde Heights, Roosevelt Drive and Nine Mile. The wells average 18.8 gallons per minute (gpm) and are 170.5 feet deep. The total reported yield of these wells is 3190 gpm or 4.6 million gallons per day. Duaime and Metesh, 1995 at p. 12 note: "There have been few if any reports of water shortages despite the intense usage."

**Table 3.10. Summary of Butte municipal water supply in the baseline[a]**

| Supply source | Water supply Million gal. / day[c] | Source of estimate |
|---|---|---|
| **(A) Groundwater**<br>Butte Hill bedrock aquifer | 7.2 to 9.9 | Maest et. al., 1995 Table ES-3, Ted Duaime and John Metesh, personal communication |
| Butte alluvial aquifer (including Area I & valley) | 2.1 to 8.9 | Maest et. al., 1995 Table ES-3<br>Montgomery 1988, Meinzer, 1914. |
| Subtotal Groundwater | 9.3 to 18.8 | |
| **(B) Surface water**<br>Moulton | 0.55 | Peccia & Assoc. 1991 |
| Basin Creek | 2.41 | Peccia & Assoc. 1991 |
| Upper Silver Bow Creek | ≤ 3.4 | Maest et. al. 1995, John Metesh, personal communication. |
| Subtotal surface water | ≤ 6.4 | |
| **(C) Total supply** | 14 to 23.5[c] | |
| **(D) Total contaminated** | 11 to 13.7 | |
| **(E) Percent contaminated** | 58% to 79% | |

[a] Baseline is the case where groundwater and surface water resources have not been impacted by mining - specifically the Butte bedrock and alluvial aquifers are uncontaminated and Upper Silver Bow Creek is available for use rather than filling the Berkley Pit.

[b] 1 million gallons per day (mgd) = 1,122 acre feet per year (ac-ft/yr).

[c] Note: for calculations of total supply and total contaminated Upper Silver Bow Creek was assumed to be 1.7 mgd.

The alluvial aquifer in the flats, including Area I, has been studied by a number of hydrologists including Meinzer (1914), Botz (1969) and Bergantino (1995). Meinzer concluded that "the quantity of water annually received by and discharged from the underground reservoir amounts to a few thousand acre-feet but is probably less than 10,000 acre-feet. A large part of this annual supply could be recovered by pumping from wells." The lower bound of some 2,000 acre-feet is almost certainly too low and the 10,000 acre-feet is a plausible upper limit (pers. comm., John Metesh). Meinzer reports on a number of wells already utilizing this aquifer by 1914, including the Clark pumping plant (located near the current Harrison Avenue-Interstate 90 interchange). The latter utilized a set of 10 wells that sustained 800 gpm (or 1.2 million gallons per day) as an average yield over a period of many days.

Meinzer concluded that with proper methods of construction a yield of 100 gpm from a single well could probably be developed in most parts of the flat. This conclusion was also reached by Botz (1969) who stated that: "Alluvium in most of the area will yield sufficient water for domestic and stock use and in selected areas will yield several hundred gallons per minute to wells". Bergantino (1995) reports on a well drilled in 1992 at the Mountain View Cemetery that yielded 250 gpm in a 12-hour test and 125 gpm in a 24-hour test. The well was designed for 300 gpm. Bergantino suggests that in certain areas of the flat a sustained yield of 300,000 gallons per day would be possible with a field of five wells at 170 to 200 feet deep. It would clearly be technically possible to develop a set of well fields to utilize the alluvial aquifer for municipal water supply in the absence of contamination, particularly along Silver Bow Creek in Area I (pers. comm., John Metesh).

It is also plausible that in the baseline situation some use would have been made of the proximate and best protected surface water resources. These are listed in Table 3.10 to include Moulton reservoir in the headwaters of Silver Bow Creek and the Basin Creek Reservoir. The magnitude of these resources is based on their actual use in the existing municipal system (Peccia & Associates 1991) (Table 3.11). Montgomery (1988) characterizes these sources as having good water quality, with mineral content levels and turbidity not likely to result in taste, odor or coloration problems. These reservoirs have been treated with copper sulphate for algae, as mentioned by both Montgomery (1988) and Meinzer (1914). Upper Silver Bow Creek, prior to mining, was used for an ice pond at the location of the current Yankee Doodle Tailings Pond. The quantity of surface water flowing from this area into the Berkeley Pit is reported by Maest et. al. (1995) as 1.69 mgd. Recently this flow has increased to 3.4 mgd (pers. comm., Ted Duaime and John Metesh). However, the estimated surface flow in the absence of mining development apparently has not been determined. Blacktail Creek is another proximate stream, but is not currently used for municipal supply. It is unlikely that this stream would have been a supply source in the baseline case. Blacktail Creek was very early on utilized for agriculture and lay along the major travel corridor over Pipestone Pass.

Using the midpoints of the various estimated water supply quantities, the total average supply from the plausible baseline system shown in Table 3.10 is 19.4 mgd average. The average subtotal for groundwater sources alone is 14.05 mgd or 75 percent of the average baseline supply. An average total of 12.35 mgd or 66 percent of the total baseline supply is currently contaminated. These average supplies are somewhat in excess of the current Butte average demand of 10.8 mgd (Table 3.12). No single resource alone is adequate on an average basis to meet the existing municipal system demand. Montgomery (1988), who of course did not consider the contaminated aquifers as a potential supply, characterized the remaining uncontaminated alluvial aquifer in the flat as providing only some "supplemental supply". It is possible that in a baseline situation, the Butte water system could be 100 percent on groundwater, most of which is currently contaminated. Montgomery (1988, p. 7-9), after reviewing the availability of alternative sources of water for the Butte municipal system, states: "Water supplies in the Butte area are limited and many water supplies currently used by others

than the Butter Water Company are of poor quality". It is very likely that, in the absence of contamination, the Butte Municipal System would have made considerable use of the groundwater resources underlying and most proximate to the city.

**Table 3.11. Butte municipal water system 1990 supply sources (million gallons per day)[a]**

| Source | Average day | Maximum day |
|---|---|---|
| Bighole River | 6.75 | 13.37 |
| South Fork | 1.06 | 5.18 |
| Basin Creek | 2.41 | 8.44 |
| Moulton | 0.55 | 1.54 |
| Total | 10.77 | 28.53 |

[a] Robert Peccia & Associates, 1991. "Butte Water System Three Year Improvements Program 1992-94." Helena, MT.

**Table 3.12. Butte municipal water system 1990 demand estimates (million gallons per day)**

| Demand category | Source of estimate | | | |
|---|---|---|---|---|
| | Montgomery 1988[a] | | Robert Peccia & Assoc. 1991[b] | |
| | Average demand | Maximum demand | Average demand | Maximum demand |
| Residential | 4.6 | 13.8 | -- | -- |
| Commercial | 0.3 | 0.9 | -- | -- |
| Industrial | 0.8 | 1.8 | -- | -- |
| Leakage | 2.4 | 2.4 | -- | -- |
| Total | 8.1 | 18.9 | 10.8 | 24.3 |

[a] James M. Montgomery, Consulting Engineers, Inc. 1988. "Butte Water System Master Plan. Table 3-1, p. 3-4.

[b] Robert Peccia & Associates, 1991. "Butte Water System Three Year Improvements Program 1992-94." Helena, MT.

### 3.3.2 Costs per household of groundwater contamination

Determination of the costs per household of a potentially mixed groundwater and surface water based municipal system depends on the degree of dependence on each of these sources. In choosing its sources, Butte in the baseline would have made its decisions based on water quality and cost. Of the surface water resources utilized by Butte today, only the Basin Creek supply is clean enough to allow the city to obtain a filtration waver for this source. Therefore, Basin Creek water would in the baseline have been desirable based on quality. In the absence of contamination, groundwater would also have been a high quality source of municipal water in the baseline.

Comparisons based on the relative cost of sources are more difficult to make due to the large imbedded costs present in the current Butte system. However, cost comparisons can be made based only on the costs associated with the recent upgrading of the Butte system conservatively ignoring imbedded costs associated with currently used water sources. Table 3.13 shows a comparison of water supply costs in dollars per million gallons per day of supply. Moulton Reservoir and the Big Hole/ S. Fork Divide Creek supplies are very costly compared to wells. Of the three currently used Butte surface water sources, only the Basin Creek supply has an upgrade price tag in the same range as the three estimates for Butte groundwater development. It should be noted that these cost comparisons consider only the upgrade costs for the surface water resources. In contrast, capital costs reported in Table 3.13 are for new wells. Based on the criteria of relative cost and quality, it appears that the most sensible combination of water sources for Butte in the baseline would be groundwater and the Basin Creek supply. Based on Table 3.11, Basin Creek currently supplies 22.4% of current Butte water needs. Therefore for this scenario we assume that the most likely baseline Butte water system would be based on 77.6% groundwater resources and 22.4% surface water.

As with the other baseline scenarios discussed previously, economic damages arise in this case because current users of the Butte municipal system face higher costs for their tapwater and, on average, pay a considerable amount to improve the quality of that tapwater (averting costs). In the baseline supply situation summarized in Table 3.10 all Butte residents who utilize the municipal water system would be better off because of the municipal system's use of groundwater. The current number of residential hookups in Butte is 9,923 (Butte Water Company, 1994). This estimate is conservative because, as discussed below, a municipal system that utilized Butte groundwater resources would be cheaper than the existing system; accordingly, the number of individuals using the municipal system (instead of private wells) would be greater than under the existing system.

In the baseline situation where the municipal system used groundwater and proximate good-quality surface sources, the tapwater would not motivate behavior such as filtering, boiling, hauling or purchasing bottled water to have access to drinkable water. Thus the estimates of averting costs developed in Table 3.3 also apply here. A portion of these household, however, have the good quality Basin Creek supply as a sole source of their municipal water (pers. comm., Jim Dennehy, Butte Water Company). We therefore assume that 22.4% of the 9,923

residential hookups incur no averting costs. Therefore, under this scenario we estimate losses due to higher water rates for all 9,923 households, and averting costs for the 7,700 households not utilizing Basin Creek water. As demonstrated by Desvousges (1995b), the averting costs for the subsample of municipal system water users living over a contaminated aquifer are not statistically different than municipal system water users living in a comparison area (Appendix B, Supporting Analysis, p. B-10). This is not a surprising result in that what these individuals have in common is their source of tapwater - the existing Butte municipal water system.

The costs for a Butte baseline municipal water system utilizing groundwater can be estimated based on the rates observed in other Montana municipal systems. As previously noted, a cost-effective baseline system that just meets average demand would, consistent with Table 3.13, utilize 77.6 percent groundwater resources and 22.4 percent surface water resources. Table 3.7, which was referenced earlier, lists the average costs per ccf of most of the larger municipal systems in Montana, and categorizes these systems as mainly groundwater or surface water. Mainly surface water systems have the highest costs in the state. (Butte, which has the highest of the rates listed in Table 3.7, is entirely on surface water.) Excluding Butte, but otherwise using the highest observed rate for a mainly groundwater system ($1.416 per ccf in Anaconda) and the highest observed rate for a mainly surface water system ($1.82 per ccf in Helena), a weighted average estimated municipal rate is computed for the Butte baseline system. We assume that 77.6% of the system would be groundwater based. Using a 77.6% share to groundwater and the highest rates in Table 3.7 leads to an estimated rate for the Butte municipal system in the baseline of $1.51 per ccf.

This approach leads to the most conservative estimate of the excess costs of the existing municipal water supply compared to the baseline that is consistent with this data. The weighted average rate for the baseline of $1.51 per ccf is 64% of the average rate in the existing Butte system. Accordingly, a baseline municipal cost per household of $340.68 for a system that utilizes Butte groundwater is consistent with the previously discussed estimate by Desvousges (1995b) for average costs per household of $533.16 per year under the existing system (see Table 3.5). The difference in these two costs, $192.48 is a measure of the loss, in addition to averting costs, for each household using the current Butte water system. The estimated annual cost per household for the Butte municipal system in this baseline is almost certainly too high and the cost differential too low. It is unlikely that in the baseline a combined Butte surface and groundwater system would have both elements with the highest average cost for the larger systems in the state. It is very likely that the baseline cost of surface water from Basin Creek would be substantially lower than the average Helena rate. The latter is relatively high due to, in part, the cost of filtration. Another plausible upper bound to costs of a largely groundwater based municipal system would be a system where every house has its own well and pressure tank. This has been specifically estimated (the cost of a self-contained private well) in Table 3.2 at 270.72 dollars. The baseline cost estimate used here of $340.68 is in excess of private well costs by 26% percent.

**Table 3.13. Comparison of cost-effectiveness of alternative Butte municipal water sources (thousands of dollars).**

| Sources | Cost per million gallons per day | |
|---|---|---|
| | Average yield | Maximum yield or capacity |
| (A) Surface water resources - Incremental cost of proposed three-year improvement program 1992-1994[a] | | |
| Moulton Reservoir | $6,474.5 | $2,312.3 |
| Big Hole / S. Fork Divide Creek | $1,405.4 | $686.0 |
| Basin Creek | $236.5 | $67.5 |
| (B) Cost estimates for new wells | | |
| Bergantino (1995) | $250.0 to 300.0 | 200.0 to 240.0 |
| Montgomery (1988) | $500.0 | |
| Private wells in bedrock aquifer[b] | | $288.0 |
| Anaconda improvements[c] | 193.7 | 103.9 |
| (C) Storage capacity | | |
| New 10 million gallon Colorado Hill tank[c] | | 287.5 |
| New 4 million gallon anaconda storage[c] | | 395.0 |

[a] Derived from Robert Peccia & Associates (1991) Table 2 and Figures 3,4,5, and 6.

[b] Based on Duaime et al. (1995) estimate of average bedrock well depth and yield, and current drilling and well development costs (Table 3.2)

[c] Derived from Robert Peccia & Associates, Anaconda Water System Improvement Program.

Based on Metesh (1995), Meinzer (1914), Botz (1969) and Bergantino (1995), a municipal system utilizing the Butte groundwater resources will tend to have more and smaller wells than some other municipal systems in Montana. It is noteworthy that this does not appear to add significantly to the average cost of well development. The well costs reported in Table 3.13 vary from $100,000 to $500,000 per mgd. Montgomery (1988) estimates the cost of a "modern municipal well" in the Butte area of 200 to 300 gpm at $500,000 per mgd capacity, including minimal land costs. By comparison, Bergantino (1995), suggests a well field of 5 wells to obtain 300,000 gallons per day at $75,000 to $90,000 including pumps but not land

costs or surface distribution pipes. This estimate is $200,000 to $240,000 per mgd capacity for wells using some areas of the alluvial aquifer.

Using the Duaime and Metesh (1995) estimate for bedrock aquifer wells and depths, Table 3.2 provides cost estimates per well (including pressure tank and pump) of $6,220 for a 15 gpm well. Utilized in the type of grid described in Metesh (1995), these costs are $288,000 per mgd capacity. Even using the latter well development cost, and installing capacity of 20 mgd to meet peak demands (along with Basin Creek), the total investment is $5.8 million. At a 10 percent nominal amortization rate this well development cost alone is only $58 per year per household, even if paid for only by the existing residential customers. Actually, if Butte was using a groundwater municipal system, the well development would likely have occurred years ago and embedded costs associated with the investment would be even lower today. Other costs associated with a municipal groundwater system include land costs, management and the distribution system. Using the actual observed costs, including embedded costs, on the more expensive Montana municipal systems provides an upper limit to the likely costs of a Butte municipal system in the baseline.

### 3.3.3 Annual Butte city-wide costs of contaminated groundwater

For the baseline scenario where the city-wide Butte municipal system is in part based on groundwater, the annual costs are $4.9 million at present and $2.4 million for 1998 into perpetuity (Table 3.14).

**Table 3.14. Total Estimated Annual Past and Future Residential Losses to 9923 households on Butte municipal system**

| Years | Municipal cost (M) | Groundwater Municipal cost (M2) | Averting costs (A) | (M-M2)*9923 +(A) * 7700[b] |
|---|---|---|---|---|
| 1981-1997 | $533.16 | $340.68 [a] | $438.41 | $5,285,736 |
| 1998 - Perpetuity | $533.16 | $340.68 | $112.39 | $2,775,382 |

[a] calculated as ($1.5065 ccf / $2.3576)* $533.16=340.68

[b] The number of households incurring averting costs has been adjusted downward by 22.4% to reflect the assumption that 22.4 % of the residential hookups would be on relatively clean Basin Creek water. This is a conservative assumption in that while Basin Creek supplies 22.4% of Butte municipal water on average, a portion of this water is mixed with water from other municipal sources and does not serve as a sole source for households in the South Butte area. Therefore, the number of households actually using Basin Creek water as their sole municipal source is less than 22.4% of Butte residential hookups.

The present net worth of damages to all 9,923 households currently utilizing the Butte municipal system is $187 to $217 million, depending on the real discount rate chosen (Table 3.15).

**Table 3.15. Calculation of present net value of past and future losses to 9,923 residential water users on the Butte municipal system.**

| Statistic | Based on Desvousges and Waters (1995) year specific real cost of capital | Based on 7% real cost of capital |
|---|---|---|
| PNW factor for 1981-1997 | 24.496068 | 28.822633 |
| PNW factor for 1998-perpetuity | 31.531069 | 12.477696 |
| Estimated 1981-1997 losses | $129,479,748 | $152,348,830 |
| Estimated 1998 to perpetuity losses | $87,510,763 | $34,630,374 |
| **Total estimated losses to residential households** | **$216,990,511** | **$186,979,204** |

## 3.4 Summary of total damages due to Butte groundwater contamination

Total damages for the three alternative baseline scenarios are summarized in Table 3.16. The most conservative estimate assumes that only private well users, not the municipal system, would in the baseline have utilized the currently contaminated groundwater sources. Based on an estimated 1790 affected households lying over the contaminated aquifers, total damages are $45 to $52 million, depending on the discount rate. The other two baseline scenarios examined arise from the likelihood that the Butte municipal system would also, in the absence of contamination, have used the currently contaminated aquifers. One such scenario conservatively assumes that only a limited municipal groundwater development would have occurred, sufficient to supply the households now lying over the contaminated aquifers. The estimate of these damages is $79 to $91 million, again depending on the discount rate. The final, and perhaps most likely baseline scenario, is that the primary water supplies for the entire Butte municipal system would have been the Butte area aquifers and Basin Creek. Under this scenario all 9,923 households currently connected to the Butte municipal system are worse off than if the currently contaminated groundwater had been used to supply municipal wells. Under this scenario, total losses are $187 to $217 million. In both of these latter scenarios, some portion of residents would have used private wells. However, since private well costs are even less than the estimated cost of a municipal system based on groundwater resources, not correcting for private wells makes the estimates for the latter scenarios more conservative.

**Table 3.16. Estimated Total Damages to Residential Water Users Due to Groundwater Contamination**

| Estimate | Based on Desvousges (1995) year specific real cost of capital | Based on 7% real cost of capital |
|---|---|---|
| Estimated losses based on lost access to private wells | $51,886,259 | $44,530,297 |
| Estimated losses based lost access to a groundwater municipal system in the contaminated area | $90,881,592 | $79,161,383 |
| Estimated losses based on lost access to a partially groundwater based municipal system | $216,990,511 | $186,979,204 |

## 4.0 AGRICULTURAL WATER VALUES

### 4.1 Literature on Agricultural Water Valuation

Duffield et al. (1991) did a study of the values of surface water used for crop production in Montana and estimated the value of water to six crops in eight Montana counties. These estimates are appropriate for use in computing net groundwater values for agriculture in the Upper Clark Fork drainage. In order to convert these surface water values into groundwater values, it is necessary to subtract the average cost of getting the groundwater to the surface. To the extent that the surface water net values include conveyance costs that would not be associated with groundwater development, this approach understates groundwater values. Groundwater development costs include the amortized fixed cost of drilling the wells and installing the pumping equipment, as well as the variable costs of operation and maintenance of the wells.

Duffield et al. (1991) showed that agricultural water values are dependent, to a large extent, on the crop being irrigated, and the climate (or location) of the land being irrigated. The 1994 Montana Agricultural Statistics summary report shows the composition of crops grown in each Montana county. For the 1993 growing year Deer Lodge County reported 14,760 acres of crops of which 12,000 (or 81.3%) were either alfalfa or other hays. For Silver Bow County, there were 10,700 acres of crops planted in 1993 with 10,000 acres (or 93.5%) being either alfalfa or other hays. The following discussion and results are based on alfalfa hay. Estimates for the value of water used to irrigate other hays are much more difficult to derive. Other hays, or pasture grasses, are often not only cut for feeding but also grazed in the later part of the growing season. While data from Montana Agricultural Statistics Service is readily available to estimate the contribution of irrigation water to the amount of pasture grasses that are cut, Montana Agricultural Statistics Service data is not available to estimate the contribution of irrigation to the number of animal unit months of grazing which can be done per acre. Since data constraints allowed only partial estimation of the value of water to other hays, the following analysis focuses on the value of irrigation water in the production of alfalfa hay.

Duffield, et al. (1991) estimated the value of surface water used in irrigation for alfalfa hay for 8 Montana counties. Silver Bow County was not included in the Duffield (1991) analysis. Additionally, Deer Lodge County water value estimates for alfalfa hay were based on small acreages and therefore had the potential for being unreliable. In order to apply the methodology of Duffield (1991) to alfalfa hay grown in Deer Lodge and Silver Bow Counties we aggregated the data used in Duffield (1991) into climactic zones, rather than counties. We also extended the time series data used to include 1989-1993 data. The agricultural areas of Deer Lodge and Silver Bow Counties lie on the border of zones 4 (moderately low consumptive use) and 5 (low consumptive use) (USDA Soil Conservation Service)(see Appendix C). In order to obtain reliable estimates for the value of irrigation water used in the production of alfalfa hay, aggregate estimates for this value were derived for all counties contained in these zones in the Northwest and Southwest Districts as defined by the Montana Agricultural Statistics Service (See Appendix C).

Table 4-1 shows the estimates of mean value of surface water used in the production of alfalfa hay in climatic zones 4 and 5 in the Northwest and Southwest Districts of Montana. These represent a starting point for analysis of the value associated with groundwater use. The estimates are presented as a range of values in order to represent alternative conveyance efficiencies for the water from the well head to the crops. Conveyance efficiencies for surface water in this area range from 25% to 75% depending on the size of the ditch and the type of soil the water flows over (personal communication, Glen Green, Resource Conservationist, NRCS, Deer Lodge). In the next sections these estimates are adjusted to account for the costs associated with developing the groundwater wells and delivering the water to the surface.

**Table 4-1. Estimated net economic values of surface water associated with the production of alfalfa hay in Northwest and Southwest Montana climatic zones (1990 $).**

| Zone | Long run values under alternative conveyance efficiencies[a] (wheel line) | | | Long run values under alternative conveyance efficiencies (center pivot) | | |
|---|---|---|---|---|---|---|
| | 25% | 50% | 75% | 25% | 50% | 75% |
| Zone 4 | 9.74 | 19.48 | 29.22 | 7.49 | 14.98 | 22.47 |
| Zone 5 | 12.82 | 25.64 | 38.46 | 9.28 | 18.55 | 27.83 |
| Average | 11.28 | 22.56 | 33.84 | 8.39 | 16.77 | 25.15 |

[a] Percentages represent typical alternative conveyance efficiencies.

The appropriateness of using the estimates shown in Table 4-1 as a base for calculation of groundwater values rests on the assumption that conveyance and application loss and conveyance and sprinkler system costs for surface water are appropriate for groundwater. If this assumption is valid then simply subtracting the costs associated with well installation and operation will yield the estimated net values of groundwater used in the production of alfalfa hays. In fact, farmers utilizing groundwater for irrigation generally have conveyance efficiencies approaching 100% as they pump water from the well into an enclosed pipe and to the sprinkler system (personal communication, Glen Green, NRCS, Deer Lodge, MT). The long run water values under the assumption of 100% conveyance efficiency would be $45.11 for wheel line irrigation and $33.54 for center pivot irrigation. An average value of $39.33 is used in the following analysis.

## 4.2 Estimation of agricultural groundwater values

In this section the average costs of groundwater wells is computed to use in deriving a net value to agricultural use of groundwater. It is first necessary to identify the typical characteristics of agricultural groundwater wells in the Upper Clark Fork Valley. Dave Strufert, the County extension agent in Deer Lodge cited only one farm with a groundwater irrigation system in place in the entire Upper Clark Fork Valley (Powell, Deer Lodge and Silver Bow counties). This farm, along Racetrack Creek, uses groundwater to feed a center pivot irrigation system. It should be noted that there were 45 registered high volume wells, yielding greater than 500 gpm in this area. Only two of these, however, could be verified as being used for agricultural production. Because of the lack of groundwater irrigation wells in the area we limit our analysis of well costs to one general class of wells: a 500 gallon per minute 10 inch well.

Table 4-2 shows estimates of costs associated with groundwater wells used in agricultural production. Costs are shown for high volume systems operating at 500 gpm in a 10 inch well averaging 160 feet deep. The acreage irrigated by this flow is based on a minimum flow necessary of 7 gpm per acre (personal communication, Soil Conservation Service Office, Missoula). Table 4-2 also assumes that the wells are operated to capacity.

Table 4-3 shows the calculation of long run net values of groundwater used in the production of alfalfa hay in the Upper Clark Fork drainage. The calculations assume that the crops are irrigated with a center pivot sprinkler system and that the total conveyance and application loss of water is 65%. This loss is not unusual for this type of system. Groundwater used in the production of alfalfa hay is estimated to have a net value of 14.39 dollars per acre foot. This estimate is based on 1990 crop prices and costs. Therefore, it appears that groundwater can be used as a profitable input to the production of alfalfa in Deer Lodge County.

**Table 4-2. Average estimated costs associated with supplying groundwater for agricultural irrigation.**

| **Characteristic / cost** | **500 gpm pump in 10" well** |
|---|---|
| Fixed costs associated with agricultural wells | |
| Average total well depth<br>Cost per foot of well depth | 160<br>$80.00 |
| Average cost of total depth | $12,800 |
| Average cost of pumping equipment | $7,000 |
| Average total fixed costs of well development and equipment | $19,800 |
| Amortized fixed costs per year of development and equipment (7.0%) for well and 10 year life for pump | $1596 |
| Average fixed costs per acre foot pumped[a] | $11.16 |
| Variable costs associated with agricultural wells | |
| Average pumping lift (feet)[c] | 70.00 |
| Average electrical costs / ac.ft. pumped[b] | $13.78 |
| Average total cost of well installation and operation per acre foot | $24.94 |

[a] Based on estimated evapotranspiration rate for alfalfa hay of 12 inches and an overall irrigation conveyance and distribution system efficiency of 65%

[b] Based on average lift, 60 psi system pressure requirement and 20 psi friction loss, 65% to 75% pumping plant efficiency, 0.037/kwh electricity cost.

[c] Based on the average depth and pumping level of high volume wells in the analysis area.

**Table 4-3. Estimation of agricultural groundwater values for hay production in Deer Lodge County based on well costs and Duffield, et al. (1991) revised estimates of net water values to agriculture (1990 dollars).**

| **Statistic** | **500 gpm well** |
|---|---|
| Alfalfa Hay | |
| Net long run value of water at the diversion (or well-head) in hay production for a system with wheel line sprinkler and 100% conveyance efficiency[a] | $39.33 |
| Long run well and operating costs | $24.94 |
| Net value per acre foot of groundwater | $14.39 |

[a] Overall conveyance and application loss assumed to be 65%

## 4.3 Prices paid for surface water for agricultural use

Irrigation districts around the state which supply water to farmers for a predetermined price are one source of information on the value of water in Montana agriculture. An informal survey of several of these irrigation districts showed delivered water prices ranging from approximately $4 to $30 per acre foot. The majority of districts contacted reported water prices in the $4 to $6 /acre foot range. No irrigation districts were located in the Anaconda and Butte areas.

The price of water supplied by the irrigation districts to farmers is based on the imbedded cost of storing and delivering that water. Some irrigation districts use small containment reservoirs while other utilize onstream diversions as water sources. In general, the water cost to the farmer reflects the long term average imbedded costs of the irrigation district. The costs of new reservoirs or diversions would likely be substantially higher than the current typical irrigation district price of $4 to $6 /acre foot.

A comparison of the water charges, reported by the contacted irrigation districts, to the net long run value of water at the diversion (reported in Table 3-3) shows that the irrigation district charges are less than the long run value of water at the diversion for production of alfalfa. This is consistent with the fact that irrigators are willing to pay $4 to $6/acre foot for water from irrigation districts. Economic theory suggests that farmers will utilize water sources which do not cost more than the net long run value of that water at the diversion.

## 5.0 ESTIMATED PRICE OF WATER RIGHTS TRANSFERS IN UPPER CLARK FORK BASIN

The State of Montana's restoration plan (State of Montana, October, 1995) includes the purchase or lease of water to: 1) replace some services of contaminated aquifers with 12,577 acre feet per year (Alternative No. 2A) for 29 years from 1996 to 2025. and 2) to augment instream flows in the Upper Clark Fork with 50 cfs flow from mid-July to mid-September (or 6,150 acre feet per year) for 40 years from year 10 of this restoration alternative to year 50 (Alternative No's. 9A, 9B, 9C). This section examines the problem of predicting the cost of obtaining this amount of water over the foreseeable future.

One likely source of this water is from current irrigation users. Irrigation is the dominant surface use in the Upper Clark Fork Basin claiming 87% of total acre feet of rights (Montana Department of Natural Resources and Conservation, 1988). Irrigation is also among the lowest valued water uses (Gibbons, 1986) and is therefore a likely source of any water rights transfers.

Not surprisingly, active markets in municipal water rights have arisen in areas with rapidly growing populations and limited water supplies. Colorado towns on the eastern slope of the Rockies and towns in the arid southwest such as Phoenix, Tucson, and Albuquerque all have purchased water rights for municipal uses in recent years.

An active market for water rights has not developed in Montana, possibly because until very recently one could still file for the use of unappropriated water in all regions of Montana. Groundwater and surface water were generally available for the cost of filing and development. Montana is now in a transition period as several major basins have been closed to water right filing. The Madison, Jefferson and Teton Basins have been permanently closed and the entire Upper Missouri River Basin above Moroney Dam is temporarily closed. The Upper Clark Fork Basin was temporarily closed by the Montana Legislature in 1991. A water management plan for this area is being developed, with the temporary closure to terminate on July 1, 1995. In 1995 S.B. 144 passed by the Montana Legislature again closed the basin to surface water appropriation and provided the closure be reviewed no less than every five years.

With basin closures, surface water rights for new uses must be obtained from existing users. Over time this will likely lead to the development of a water market in closed basins. Evidence on the likely level of prices is limited. However, Montana Department of Fish, Wildlife and Parks has in recent years leased water for instream flow in the Yellowstone Basin - which is not closed. One lease costing $7,500 a year on Mill Creek is for about $3/acre foot. However, this is for salvage water. Another lease for $12,000/year has a cost per acre foot of $56, though this price includes the cost of monitoring the water allocation on this stream (Liter Spence, personal communication).

Based on the experience in Southwestern United States water markets, prices for water transfers will be between the seller's reservation price (minimum the seller will accept) and the buyer's willingness to pay (Saliba et al., 1987). The buyers willingness to pay in this case is not obvious since the use would presumably be mandated in a litigation setting. If the seller is

using water to irrigate alfalfa, the reservation price is the acre-foot values for surface water previously discussed - on the order of $8 to $34 per acre foot per year. The experience of the Montana Department of Fish, Wildlife and Parks water leasing program is that it is difficult to obtain long term water rights leases from irrigators. One counteroffer the department has received that does not entail salvage water was for an annual lease rate of $70.50 per acre foot for a 1,417.5 acre foot per year right in the Upper Bighole Basin (pers. comm., Liter Spence, MT DFWP). This was five times higher than the highest plausible reservation price for this particular right - $13 per acre-foot (Duffield et.al. 1991). It seems likely that long-term leases will not be available from irrigators at the reservation price. This is also supported by the general experience in Southwestern water markets. Saliba et al. note (at 38): "prices tend to be lower when the predominant buyer for the water rights is irrigated agriculture ... and nonagricultural water users do not compete significantly for water with irrigators. Prices tend to be higher where expanding nonirrigation water users face institutional barriers and/or physical supply limits in seeking additional water supplies." Ranchers may also view water rights "as an appreciating asset and add speculative value to their reserve price" (Saliba et al. 1987 at 34).

It is likely that the water rights sought for the restoration plan would be purchased near the point of application to minimize transportation costs. This means that the 12,577 acre feet per year right could come from Silver Bow County irrigated agriculture and the 50 cfs right from the Deer Lodge County area. In both cases the rights sought are significant compared to the total irrigated water use in the respective counties - on the order of 10 to 20 percent. In short, the situation is one where nonirrigation water users would want to purchase rights in a basin that may well be closed for further appropriations. Based on experience in the Southwest, this would suggest prices somewhat higher than the reservation price.

Another possible source of water for restoration alternatives 2A and 9A, 9B, and 9C is the 13,138 acre-foot Silver Lake water supply in the headwaters of Warm Springs Creek. This resource was recommended to the Butte Water Company as the primary supply (along with the Basin Creek Reservoir) for meeting Butte's water supply needs in the Montgomery (1988) Butte Water System Master Plan. A lease agreement, in memorandum form, was reached in 1987 between Dennis Washington and the Butte Water Company that would have produced 11 million gallons per day (or 17 cfs). The annual cost over a proposed ten year lease term was reported to be $69 per acre-foot, with the option of a second ten year renewal. This water source was also mentioned in connection with a bid to Micron Technology Inc. to locate a manufacturing plant near Butte (Hieger 1995). No specific prices were mentioned in connection with the Silver Lake supply in this instance.

To conclude, there is considerable uncertainty in predicting prices for long-term water rights transfers in the Upper Clark Fork Basin. Reservation prices for water rights transferred from irrigated agriculture could be as low as $8 to $34 per acre-foot depending on the irrigation system. But it seems unlikely that ranchers would lease at the value of their marginal product. The only offers for substantial water rights transfers to nonirrigation uses that were identified

in the area are both for around $70 per acre-foot, and these were made some years ago. It is likely that prices on the order of $40 to $50 an acre-foot or more may be necessary to secure rights of the magnitude and term described in the restoration report.

## 6.0 VALUING A MARGINAL CHANGE IN MUNICIPAL WATER SUPPLY

### 6.1 Concepts

The most comprehensive review of the literature on municipal water values is by Gibbons (1986). She focuses on measuring the value of an incremental change in water supply as illustrated in Figure 6-1. The latter provides an estimate of the consumer surplus (net willingness to pay over and above the given price or area ABC in Figure 6.1) that municipal water customers realize from an increment in water supply. Note that this approach assumes that the water is essentially "free" to the municipality. If the municipality in fact has to purchase water rights to obtain the water, this unit price needs to be added to the consumer surplus estimate.

This approach to groundwater valuation could be applicable if a groundwater resource was used to provide an increment in supply (such as from Q1 to Q2 in Figure 6.1). Note that unless supply is increased to Q2, demand exceeds supply at price P1 (there is a water "shortage"). If a water shortage has existed in the past or will exist in the future because of groundwater contamination, this approach provides a measure of the lost use value.

In order to estimate the lost use area ABC one would need to know the change in supply (Q2 minus Q1), the price and the shape and location of the demand curve (the line passing through A and B in Figure 6.1). Obviously the larger the reduction in use and the steeper (more inelastic) the demand curve, the larger is the unit (per acre foot or per cfs) consumer surplus loss. To date there are no estimates of the shape or location of the municipal demand for water in the Clark Fork Basin communities. However, Young et al. (1972) provide a method for estimating the area ABC using a) an assumed constant price elasticity of demand (through the region of the supply shift) based on the economics literature, b) the actual price for municipal water for the community of interest, and c) an assumed (or actual) reduction in municipal water supply (the extent of the "shortage"). It should be noted that implicitly (in Figure 6.1) it is also assumed that marginal and average costs are constant and equal to price.

In the remainder of this section we provide a brief mathematical description of Young's method, a review of the economics literature on the elasticity of demand for residential water uses and an estimate of the marginal value of municipal water.

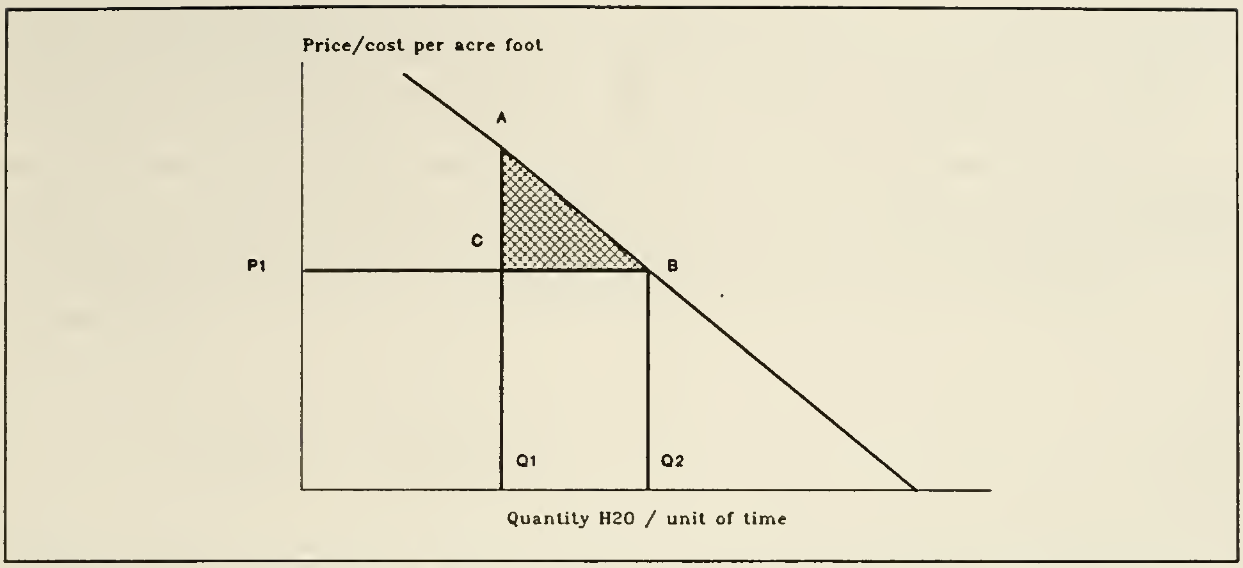


Figure 6.1. Consumer surplus for a given municipal water price and quantity change.

## 6.2 Estimating Marginal Municipal Water Values using Elasticity of Demand

Following Young (1972), for a given change in water supply (from $Q_1$ to $Q_2$) the total value of water is equal to the area under the demand curve. This area can be described mathematically as

$$TV = \int_{Q_1}^{Q_2} P(q)\, dq \qquad (1)$$

If the price elasticity of demand is constant over the range from $Q_1$ to $Q_2$, and is not equal to -1, and a point on the demand curve is known, the above equation can be rewritten as

$$TV = \left[ \frac{P\, Q_2^{x}}{1 - x} \left( \frac{Q_2}{Q_2^{x}} - \frac{Q_1}{Q_1^{x}} \right) \right] \qquad (2)$$

Where:

P = price per acre foot of water
Q2 = quantity demanded (acre feet) at P
Q1 = new quantity
x = 1/abs(price elasticity of demand)

The area described by equation 1 above is shown graphically in Figure 6.1, as defined by A B Q2 Q1. The portion of this area which represents the consumer surplus accruing to municipal water customers is the area above the municipal price level (P1) and below the demand curve. This is the triangle described by ABC in the graph. This area represents net willingness to pay for municipal water, above what one must pay (the marginal price). The total value estimate from equations 1 or 2 can be translated into a net willingness to pay (NET WTP) value per acre foot by dividing the total value by the change in quantity (Q2-Q1) and subtracting out the price per acre foot charged for municipal water (Equation 3). By assumption price is equal to average and marginal costs.

$$NET\ WTP = \left[\frac{TV}{(Q_2 - Q_1)}\right] - P \qquad (3)$$

The calculation of net WTP from equations 2 and 3 can be accomplished using a percentage change in quantity rather than a specific volume reduction. For estimating a percentage change, it is not necessary to know the initial quantity consumed at price P. Equations 4 and 5 show the formula for calculating net WTP for a percentage decrease in use (A 10% decrease in water quantity was used in the application described below.)

Where: r = Percentage reduction expressed as a decimal (10% reduction- r=.10)

$$NET\ WTP = \left[\frac{TV}{r}\right] - P \qquad (4)$$

$$TV = \left[\frac{P}{1-x}\left(1 - \frac{(1-r)}{(1-r)^{x}}\right)\right] \qquad (5)$$

## 6.3 Literature Estimates of Price Elasticity of Demand

In order to utilize Young's method, one needs to have an estimate of elasticity of demand. This responsiveness, or price elasticity of demand, represents the percentage change in quantity demanded from a 1% change in the price of the water. Gibbons (1986) noted that several studies (Danielson, 1977; Howe and Linaweaver, 1967; Young, 1973) have found that estimates of summer price responsiveness are more elastic than those of winter. This makes intuitive sense as summer residential consumption is significantly greater than winter, due to outdoor water uses

such as lawn watering. It is easier to reduce consumption of water for lawn watering than for drinking, cooking, and bathing. Therefore, the price responsiveness of demand for water tends to be more elastic in the summer than in the winter.

There have been a number of studies of municipal water demand which provide estimates of the price elasticity of demand for residential water use. Two somewhat overlapping surveys of this literature are provided by Wong (1972) and Gibbons (1986). These two surveys provide a range of price elasticity estimates. Wong cites 18 separate estimates and Gibbons provides citations for an additional 5 elasticity estimates. Additionally, Colander and Haliwanger (1979) provide refinements on Young's (1973) estimates and Renzetti (1992) provides his own estimates of residential price elasticities.

The overall range of elasticity estimates in the literature varies between -0.02 and -1.24. The majority of the estimates in this range are based on cross-sectional rather than time-series data. Colander and Haliwanger (1979) argue that in the case of demand for municipal water time-series elasticity estimates are more appropriate and tend to be more inelastic than cross-sectional elasticities. Time-series estimates are more appropriate, they point out, because cross-sectional data capture long-run structural differences and are most useful for estimating long-run demand curves useful in long range planning. For an established community, however, adjustment to water price changes is much more costly (one does not buy a new house with a smaller lawn because the price of water increases by 10%). For the purposes of examining the impact of water shortages on a given community, elasticity estimates based on time series data may be more appropriate.

Table 6.1 shows estimates of price elasticity of demand derived from time-series data as presented in Gibbons (1986). The range of these elasticities is from -0.02 to -0.63.

**Table 6.1. Estimates of price elasticity of demand for municipal water derived from time-series data.**

| Study and date | Location / estimation notes | Price elasticity estimate |
|---|---|---|
| Wong (1972) | Chicago / city sample | -0.02 |
| Wong (1972) | Chicago / suburbs sample | -0.28 |
| Young (1973) | Tucson / sample 1 (1946-65) | -0.62 |
| Young (1973) | Tucson / sample 2 (1965-71) | -0.41 |
| Danielson (1977) | Raleigh, NC | -0.27 |
| Billings and Agthe (1980) | Tucson / log specification | -0.39 |
| Billings and Agthe (1980) | Tucson / linear specification | -0.63 |

Source: Gibbons (1986)

### 6.4 An Application of Young's Method (Gibbons 1986)

Gibbons (1986) provides an example of estimated marginal values for municipal water use based on published elasticities of demand for Tucson, Raleigh, and Toronto (Table 6.2). She uses actual prices for these localities and assumed reductions in supply ranging from 1/4 to 2 ccf/month (100 cubic feet per month) and also for a 10 percent reduction in supply.

The values she computes range from $17/acre foot to $105 depending on the season and locality for the 10 percent reduction. Her estimates are in 1980 dollars; inflating these to 1993 price levels using the CPI-U generates a value range of $30 to $184. Note that the prices reported by Gibbons in Table 6.2 are in dollars per ccf; as an example of prices in dollars per acre foot the value for Raleigh in 1993 dollars is $968. This is in the same range as current prices for municipal water at Butte ($1027/af for an assumed average monthly consumption of 2500 cubic feet).

### Marginal Values for Residential Water Demand

| Locality and date of data | Season | Price (1980 dollars/ ccf)[a] | Elasticity | Average consumption (ccf/household/ month) | Marginal water values (1980 dollars/acre-foot) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Reductions from the average monthly consumption (ccf) | | | | 10 percent reduction |
| | | | | | ¼ | ½ | 1 | 2 | |
| Tucson, Ariz., 1979 | Winter | 0.72 | −0.23 | 9.44 | 19 | 40 | 89 | 225 | 82 |
| | Summer | 0.83 | −0.70 | 16.43 | 4 | 8 | 17 | 35 | 28 |
| Raleigh, N.C., 1973 | Winter | 1.27 | −0.305 | 7.82 | 30 | 64 | 142 | 358 | 105 |
| | Summer | 1.23 | −1.380 | 8.81 | 6 | 11 | 24 | — | 21 |
| Toronto, Ont., 1967 | Winter | 0.79 | −0.75 | 5.30 | 11 | 23 | 51 | 124 | 25 |
| | Summer | 0.79 | −1.07 | 6.55 | 6 | 13 | 27 | — | 17 |

*Note*: Dashes = not applicable.

*Sources:* Leon E. Danielson, "Estimation of Residential Water Demand," Economics Research Report no. 39 (North Carolina State University at Raleigh, October 1977); Angelo P. Grima, *Residential Water Demand: Alternative Choices for Management* (Toronto, Ontario, University of Toronto Press, 1972); Charles W. Howe and F. P. Linaweaver, Jr., "The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure," *Water Resources Research* vol. 3, no. 1 (first quarter 1967) pp. 13–32; Robert A. Young, "Price Elasticity of Demand for Municipal Water: A Case Study of Tuscon, Arizona," *Water Resources Research* vol. 9, no. 4 (August 1973) pp. 1068–1072.

[a] All prices have been converted to 1980 dollars by using the fixed-weighted GNP price index; ccf = hundred cubic feet.

## 7.0 CRITIQUE OF ARCO'S GROUNDWATER DAMAGES REPORT

This section provides a critique of the William H. Desvousges expert report, "Volume V. Report on Potential Economic Losses Associated with Groundwater" (July 13, 1995). This report provides an estimate of the potential economic losses associated with groundwater impacts due to mining near Butte, Montana. The report finds that potential service reductions are limited to foregone use of private groundwater wells for drinking water, affecting at most 65 or as few as 41 Butte households. Damages are measured by the excess costs of the available substitute, Butte municipal water, over the cost of private wells plus the averting costs associated with improving the low quality of Butte municipal water system tapwater. Based on survey data, the report's annual municipal cost estimate averages $534, well costs average $218 annually, and averting costs average $507. Averting costs are assumed to end in 1997. Using estimates of the after-tax rates of return available to individuals in 20 year Treasury bonds for a discount rate (Desvousges and Waters 1995, Appendix D), the present net worth of damages from 1981 into perpetuity are estimated to be $1,486,000.

The key issues and parameters that this estimate depends on include the following: spatial extent of the injured aquifers, characterization of baseline services, theoretical basis for economic damages, number of households potentially affected, costs per household (municipal, well and averting), and aggregation procedure (including choice of discount rate). On a number of these issues Desvousges (1995b) has made important errors that undermine the credibility of the reported damage estimate. Each of these key issues is discussed in turn in the following subsections.

### 7.1 Spatial Extent of the Injured Aquifers

Desvousges (1995b) relies on the opinions of Steven Larson, ARCO's expert hydrologist, on the spatial extent of the injured Butte aquifers. Desvousges' interpretation (at p. 5) of Larson's opinions is that impacts are only acknowledged to be present in the alluvial aquifer and that: "There is no information upon which to conclude that weathered bedrock has been impacted by mining. Generally, the bedrock is not a groundwater resource that provides services." Accordingly, instead of the approximately 3,500 households living over both contaminated aquifers being potentially affected, Desvousges considers only the 466 households ARCO identifies as residing in the affected area over the contaminated alluvial aquifer. The issue of whether the bedrock aquifer is impacted and capable of providing services leads to a nearly order of magnitude difference in the potentially affected population (and, other things equal, damages). This is an issue to be resolved by hydrologists. As discussed in section 3.0 of the current report, the State of Montana's expert hydrologists believe the bedrock aquifer is impacted and that it is capable of providing drinking water services (Maest et. al. 1995; Metesh 1995; Duaime and Metesh 1995).

## 7.2 Characterization of Baseline Services

A key issue in estimating groundwater damages is the characterization of what services would have been provided by the impacted aquifer in the baseline or without-mining-impacts case. Desvousges (1995b) makes an important error in concluding that potential service reductions are limited to drinking water services from individual groundwater wells. At p. 5, he notes: "Finally, the alluvial aquifer is incapable of supporting municipal drinking water services (James M. Montgomery Consulting Engineers, Inc., 1988, p. 4-11)." This is a very misleading characterization of Montgomery's findings. Montgomery was not addressing the question of what use would be made of Butte's aquifers in the absence of contamination. Montgomery was examining the situation at hand and his conclusions are contingent on the fact that the extensively contaminated portions of the alluvial aquifer are not useable. He in fact concludes that "some supplemental supply could be developed" (at 4-11). His conclusions may well have been very different if the entire alluvial aquifer was uncontaminated and available for use. Secondly, it appears that Montgomery did not undertake a very careful evaluation of what groundwater services are available even in the currently uncontaminated aquifer. He states (at 4-9) that "Little data is available on wells in the vicinity of the City but it is apparent that those wells that have been drilled produce less than would be desirable for municipal wells. That is, verbal reports are of 'good wells' that produce '100 gallons per minute or so'." His investigations apparently did not go beyond "verbal reports" and the possibility of economically viable wells at the capacity mentioned for municipal supply are not even discussed. To conclude, Desvousges' (1995a) reliance on Montgomery to dismiss the most plausible baseline use of clean aquifers under and in the near proximity to a major municipality is naive and/or misguided. Montgomery is clearly not directly addressing the hypothetical of what uses would be made of the currently contaminated aquifers in the absence of mining impacts.

The remainder of Desvousges' (1995b) analysis is fatally flawed by this arbitrary exclusion of municipal drinking water services in the baseline. Desvousges' conclusion is additionally at odds with data he cites concerning the proportion of drinking water services in major Montana municipalities that are supported by private well use. For example, Desvousges (1995a) notes (at p. 23, footnote 15) that the percentage of wells in other urbanized areas of Montana is quite low - for example 3.2 percent in Missoula and 1.2 percent in Deer Lodge. Desvousges does not bother to note that in these cities the other 99 to 97 percent of drinking water use is based on municipal groundwater systems.

In the remainder of this section, other elements of the Desvousges (1995b) analysis are evaluated. The important point here is that his conclusions ride heavily on excluding from consideration municipal drinking water services in the baseline. His maintained hypothesis is that in the baseline one would have the Butte municipal water system as it currently exists - very costly and delivering water that is judged by its customers to be of generally low quality and often undrinkable. This particular baseline scenario corresponds to only the first of three scenarios considered in this current report (section 3.1 above).

## 7.3 Theoretical Basis for Economic Damages

Desvousges (1995b) and the current report (see section 3.0 and Figure 3.1) are generally in agreement that cost savings are an appropriate approach to measuring damages to groundwater use in this application. However, it is odd that the theoretical discussion provided in Desvousges (1995b), specifically Figure 4-1, is inconsistent with the Economic Law of Demand. In particular, it is not clear why the demand for at least averting behavior services is not downward sloping and consistent with additional consumer surplus loss due to price response. In short, the specific theoretical basis provided by Desvousges (1995b) will lead to consistent underestimates of damages due to ignoring the welfare triangle labeled ABC in the current report (Figure 3.1).

## 7.4 Number of Households Potentially Affected

The number of households identified by Desvousges (1995b) as being over the contaminated alluvial aquifer and thereby potentially prevented from using a private groundwater well totals 466. As noted earlier, this number is a function of Desvousges' interpretation of the spatial extent of injury and the characterization of baseline services. Desvousges uses two approaches to identifying how many of these 466 households are actually worse off due to groundwater contamination. The first approach is based on survey responses to the Desvousges (1995b) survey questions J-1 to J-4 (see Appendix D.1). These questions are misguided in that they essentially probe respondent knowledge of injury to groundwater resources in the affected aquifer. In response to a question on reasons for not using a well, only respondents who note health concerns or reply that water is unsafe for drinking and mention the appropriate mining-related reasons qualify as potentially affected. Desvousges (1995b) identifies only 24 such respondents. In addition one respondent had discontinued use of a well for a total of 25 affected respondents or 9 percent of the sample. This is quite an elaborate hurdle and has little to do with identifying the relevant parameter - what proportion of respondents are worse off due to the contaminated aquifer. Additionally, the question itself is not very successful from a survey methodology standpoint in that the vast majority of respondents either had never considered this question (121 of 286 or 42%) or did not perceive they had a choice (57 or 28% noted that they were required to be on public water supply). In short, the question does not provide any insight into the hypothetical of what respondents would do if their aquifer was uncontaminated, but instead elicited fairly pragmatic responses reflecting the current reality.

Interestingly, Desvousges (1995b) also asks the right kind of question, but does not choose to utilize the results. In J-5 (see Appendix D.1) respondents are asked "Suppose that your household had a choice between a well and the public water supply. If the quality of water was equally good from both sources and **all other factors**, including costs and taste, **were the same**, would your household rather use a well or the public water supply?" (emphasis in the original). This question identifies the respondents that are worse off because they can not have a groundwater well. A total of 33.6 percent of respondents state that they would prefer a well under these circumstances. That this kind of question is the appropriate basis for identifying the potentially affected respondents appears to have been recognized by ARCO's consultants,

but was not utilized. For example, a memo dated February 14, 1995 from KEM re: MT-AB: Damage methodology (see Appendix D.2) specifically addresses (p. 2) the issue of "who counts" and queries: "How will we reconcile the response of J1-J4 with the response to J5? Because J5 is a hypothetical question, recommend that responses to J1-J4 be the deciding factor." A handwritten note on the document counters: "There is not a reconciliation issue - there is the issue of using the hypothetical answer or no information." Additionally, it is apparent from other memos (e.g. Sharon Snow to William H. Desvousges, May 10, 1995 - see Appendix D.3) that ARCO's consultants at one point were using a range of 24 to 102 households where the high end would be based in part on the J5 responses. This memo makes it evident that there was apparently some pressure to not utilize this more correct approach (e.g. "this can be in our pockets if they start to have a lot of problems with the 102 number"; see Appendix D.3).

To conclude, there is evidence that ARCO's consultants recognized that a question like J5 was the correct approach to the "who counts" issue.

A related point is that while J5 is the right kind of question, the situation posed obviously does not correspond to the reality of Desvousges' maintained hypothesis concerning the baseline. Contrary to the text of J5, the existing Butte municipal water system does not provide tapwater of the same cost and quality as an uncontaminated alluvial aquifer. This is amply demonstrated by Desvousges' own estimates of relative well and municipal system costs as well as averting behavior expenditures. This point is discussed further in section 3.1.2 and Appendix B, section 8.0 and Table B.3 where the Desvousges (1995b) question J5 responses are compared to responses to a question that correctly characterizes the choice (e.g. what if well water were cheaper and better quality).

Desvousges (1995b) chooses to exclude households occupied by renters from the group that could practically install wells. However, for this group of households, the problem is that Desvousges fails to survey the appropriate set of decision makers. As shown in the current report (Section 3.1.2), landlords may well prefer to have a private well for their rentals rather than be on the municipal water system. This error by Desvousges (1995b) leads to a downward bias in the estimated number of affected households.

The other approach taken by Desvousges on this issue is to identify the percent of households that actually have wells in southwestern Montana. This percentage is reported to be 14%. The two estimates (9% and 14%) lead to the reported range in total potentially affected households identified by Desvousges (1995b at p. 23) of 41 to 65. The data on which the 14% estimate is based is provided in a document labeled AB-1005, TER000020286-290 (see Appendix D.4). This listing of southwestern Montana cities and towns actually shows a very considerable range in private well use from 0.00% to 93.62%. The use of the average percent on private wells here is a transfer analysis of the most casual variety. The implicit assumption is essentially that the situation in Butte regarding private well versus municipal system use is identical to the "average" situation in southwest Montana. Contrary to the guidance on the benefits transfer literature cited by Desvousges (1995a at p. 8), there is no attempt here to document or

examine this similarity. It is very unlikely that the average municipal system in southwestern Montana has rates or water quality comparable to Butte's. Accordingly, Desvousges use of a 14% estimate is clearly unreliable.

To conclude on this point, the procedures utilized by Desvousges (1995b) to identify the potentially impacted households are badly flawed and have no basis in theory or reality.

### 7.5 Costs per Household (Municipal, Well and Averting)

The current report and Desvousges (1995b) are in substantial agreement as to the costs per household of the existing municipal system, private wells, and averting costs. However, as discussed in a previous section of the current report (3.1.4), there are some apparent typographic errors in the Desvousges averting cost estimates which, if corrected, reduce average estimated costs by about $70 per household. Additionally, the Desvousges estimates are conservative in that no opportunity cost for time used boiling water is included and vehicle travel is costed at gasoline costs rather than the full costs of operating a vehicle. There is no justification for the latter given the long-term nature of the observed averting behavior. As also noted in section 3.1.4, there is support in the literature for these methodological changes (Abdalla 1990).

A remaining issue regarding the averting cost estimates is the possibility that they are biased downward, perhaps due to survey procedures. Table B.2 in the current report compares the response to the Desvousges (1995b) survey and a more recent telephone survey of Butte households. The response in the Desvousges survey to a question on "percent who were aware of a 'boil order'" is only 64.6% compared to 87.2% in the most recent survey for a very similar question. In this case there is a convenient benchmark in reality: nearly 100% of respondents (who are nearly all on the Butte municipal water system) would have received boil orders in recent years. It is odd that only 65% of the Desvousges respondents were aware of this. Part of the problem may be in the survey protocol for selecting respondents within the household. For example, in the Desvousges (1995b) list of "Sample Questions and Answers for Montana Water Quality Study" (see Appendix D.5), respondents who state: "My husband/wife knows the most about water quality in our home, but he/she is out-of-town/unavailable/etc. for the next two months". The answer is: "If your spouse is unavailable, we would like you to take the survey...". There is a possibility that this approach may have led to many respondents who are not well informed about the issue; this could lead to biased estimates for the household. This issue could be investigated by an analysis of the Desvousges (1995b) responses to Interview Evaluation Questions. This data was requested several weeks prior to the transmittal date of the current report, but was received from TER too late for analysis.

It is noteworthy that with regard to averting costs (also referred to as averting behavior or AB), ARCO consultants had the expectation that: "households that count and those that don't will have very similar AB's" (see Appendix D.2, p. TER000031393). In fact Desvousges (1995(b), Appendix B, p. B-10) demonstrates that averting costs are not statistically different

between the affected area and the comparison area (outside the contaminated aquifer zone). This is not surprising given that what respondents have in common is the same municipal water system. This point supports the view that what Desvousges (1995b) has constructed as baseline and a measure of "who counts" is essentially arbitrary. His flawed methods obscure the reality that the handful of households (numbering only 41 to 65 in total) that he identifies as "potentially affected" and most of the remaining some 9,900 households in Butte using the municipal water system all have in common the same low quality tapwater and the need to incur very substantial averting costs.

## 7.6 Aggregation Procedures

Desvousges (1995b) chooses to use a Monte Carlo procedure to provide a best estimate of damages. Since his range of estimates on the key parameters are drawn from normal or uniform distributions, this approach is essentially computationally equivalent to merely using the average of his range on these parameters. The Monte Carlo approach merely obscures the aggregation procedure and in this application is computationally inefficient.

Desvousges (1995b) chooses to assume that averting costs end in 1997. There is no basis for this choice, which is in fact inconsistent with his own survey data (see the discussion in the current report section 3.1.4 and Table 3.4). Other end dates were evidently considered by ARCO consultants; for example an end date for averting costs in the year 2005 was used in one spreadsheet provided on disk during discovery.

# 8.0 EVALUATION OF ARCO'S COMMENTS ON THE STATE OF MONTANA GROUNDWATER VALUATION REPORT

This section provides an evaluation of the expert report by William H. Desvousges, "Volume IV, Critique of the State of Montana's Groundwater Valuation" (July 13, 1995). This report concludes that the studies the State of Montana has relied upon for estimates of the agricultural value of surface and groundwater and various methods for estimating the value of municipal groundwater (including cost savings, demand analysis, and water rights transactions) are flawed and result in unreliable estimates. These studies include Duffield et. al. 1991 "Market Value of Water Leased for Instream Flows", and Duffield 1995 "Literature Review and Estimation of Municipal and Agricultural Values of Groundwater Uses in the Upper Clark Fork River Drainage". In the following subsections, the major points in Desvousges 1995a (Volume IV) are reviewed in turn.

## 8.1 Estimates of the Agricultural Value of Water in Deer Lodge County

Duffield et. al. 1991 provide estimates of the agricultural value of surface water in various applications and for a number of Montana counties. These estimates for alfalfa hay and other hays in Deer Lodge County are the focus of the Desvousges (1995a) critique. The latter takes

note of the Duffield et. al. 1991 finding that for a farm budget approach to valuation, the samples available for Deer Lodge County are small and may be unreliable. Section 4.0 of the current report provides revised estimates based the climatic zones which include Deer Lodge County. Desvousges (1995a) is also critical of the specific valuation methods used by Duffield et.al. 1991. However, these methods are widely used in the literature and the Duffield et. al. 1991 estimates are also within the range of literature estimates (Gibbons 1986). Desvousges (1995a) is critical of the irrigation efficiencies used by Duffield et. al. 1991. On this point Desvousges is confusing overall irrigation efficiencies with conveyance efficiencies alone, and is in error. The current report (section 4.0) as well as the original report provides estimates for a range of efficiencies consistent with both actual practice and the overall efficiencies cited by Desvousges (1995a). Desvousges is also critical of other data including estimates of net irrigation data, which was not available specific to Deer Lodge County. The current revised estimates (section 4.0) utilize net irrigation data for the climatic zones of interest.

### 8.2 Use of Duffield et.al. Values in Restoration Costing

Desvousges (1995a) criticizes the State of Montana's use of the Duffield et. al. 1991 estimates of the surface value of agricultural water in Deer Lodge County as the basis for the likely price of leased water for restoration alternatives. The criticism is that the estimates are unsound and that there is no assurance that water lease prices will be equal to agricultural water values. As noted in the previous subsection, revised and reliable estimates of the value of surface water in Deer Lodge County are provided in the current report section 4.0. As also discussed in the current report, section 5.0, there is no claim that lease prices will equal the value of surface water to irrigators. The latter are rather a lower bound to the plausible range of likely lease prices. The upper bound is best indicated by actual lease price offers in the Butte-Deer Lodge County area which are, as economic theory and evidence from water markets elsewhere suggests, considerably above agricultural water values.

### 8.3 Estimates of Agricultural Groundwater Values

Desvousges (1995a) is critical of the Duffield 1995 estimate of agricultural groundwater values because they are derived from the unreliable Duffield et. al. 1991 estimates for surface water values for Deer Lodge County, because Deer Lodge values are assumed to hold for Silver Bow County, and because alfalfa values (rather than other hays) are emphasized. As noted, revised reliable estimates for Deer Lodge County surface water values are provided in section 4.0 of the current report. Because the latter are based on climatic zones, which also include Silver Bow County, they are also reliable for Silver Bow. Other hays are the other important irrigated crop (besides alfalfa) in these counties and climatic zones. However, other hay values are underestimated by farm budget estimates that do not account for the common practice of grazing other hays rather than putting up an additional cutting.

### 8.4 Cost Savings Approach to Municipal Groundwater Values

Desvousges (1995a) is critical of the Duffield 1995 estimate of damages to Butte groundwater for the following stated reasons: 1) the bedrock aquifer is not injured, 2) the state assumes all households would have a well, and 3) the fact that most Butte municipal customers are on a flat (rather than metered) rate is ignored - which leads to erroneous estimates of the actual cost of Butte municipal service. Point 1) is based on the opinion of ARCO's expert hydrologist, Steven P. Larson. The State of Montana's expert hydrologists disagree. The baseline scenario implicitly assumed in point 2) is one where the municipal system in the baseline is the existing Butte municipal system. For this setting, discussed in section 3.1 of the current report, the proportion of households that would have a well, 51%, is now based on survey data. Estimates of municipal costs in the current report have been revised (see section 3.1.3) to take account of the criticism in point 3. The current report actually uses the municipal cost estimate developed in Desvousges (1995b).

It is noteworthy that Desvousges (1995a) is not critical of the general approach of valuing municipal groundwater damages through cost savings. This is in fact the method utilized by ARCO to value groundwater damages (Desvousges 1995b).

### 8.5 Demand Analysis Approach to Valuing Municipal Uses of Groundwater

Desvousges (1995a) is critical of the Duffield (1995) analysis of the value of potential municipal water shortages. The points of criticism are that: 1) the state assumes, contrary to ARCO's interpretation of the facts, that there is a shortage of municipal water in Butte, 2) the dual pricing structure in Butte is not taken account of in application, 3) the comparison to bottled water is absurd, 4) use of Billing's data is inappropriate, and 5) the estimated model based on Billing's data is not robust. With respect to the first point, Desvousges (1995a) misinterprets the state's valuation estimate using a hypothetical reduction in municipal supplies as implying that shortages have actually been identified. In point of fact, Peccia (1991) noted (at p. 1) that the Butte Water Company "currently restricts new consumer hookups because of concern over its ability to deliver adequate water volumes". The estimates in the current report are conservative in that potential losses associated with restrictions have not been quantified. With respect to points 2, 4 and 5, the current report's estimates of the consumer surplus values associated with municipal water shortages are based entirely on the published literature (see section 6.0).

Point 3 is a misinterpretation of the Duffield 1995 discussion of the price of bottled water. It is correctly observed in Duffield 1995 that the price of bottled water indicates that the marginal value of small quantities of drinking water is quite high. Desvousges' criticism here is somewhat ironic in that Desvousges 1995b provides substantial survey-based evidence that the price of bottled water may well be relevant for valuing municipal groundwater. The costs of bottled water are a substantial component of ARCO's estimates of averting costs.

## 8.6 Water Rights Transactions

With regard to Duffield's (1995) valuation of water through water rights transactions, Desvousges observes that there are no active water rights markets in Montana so that any transfer prices available are not representative of those that would result "in an active or competitive market". Additionally, Desvousges is critical of the listing of actual transfer prices from other United States market regions (though Duffield's (1995) disclaimer of their direct application to Montana is acknowledged by Desvousges). Finally, Desvousges observes that water rights prices are not measures of consumer surpluses. The latter are the theoretically correct measure for damages based on compensable values (e.g. lost use and nonuse values).

Desvousges' observation that water prices are not themselves consumer surplus measures reveals that Desvousges has misunderstood the application of water rights transfer prices to the State of Montana's damage estimates. The purpose of examining water rights transactions is to provide a basis for actual costs of leased water in the State's restoration analysis (for example, see the discussion in the current report, section 5.0). For this purpose, costs (not consumer surplus) are an appropriate measure to be used in developing damage estimates (43 C.F.R. Part 11). The current discussion of this issue (section 5.0) correctly draws on experience in existing water markets to make generalizations that are theoretically consistent and applicable to the potential water rights market in the Upper Clark Fork Basin. As in the previous report (Duffield 1995), there is no claim that water prices from other regions themselves are transferable. While the actual evidence on water rights transactions and offers in the Upper Clark Fork Basin is acknowledged to be limited, the available information is interpreted consistent with the guidance for cost-estimating methodologies in 43 C.F.R. Part 11 as a basis for a restoration cost estimate.

# REFERENCES

Abdalla, Charles W. 1990. "Measuring Economic Losses from Ground Water Contamination: An investigation of Household Avoidance Costs." Water Resources Bulletin vol. 26, no. 3, p. 451-463.

Bergantino, Bob. 1995. Evaluation of Ground-Water Availability in the Vicinity of T3N, R7W, S31 SE1/4. Butte-Silver Bow, Montana.

Botz, M.K. 1969. Hydrogeology of the Upper Silver Bow Creek Drainage Area, Montana. Bulletin 75. Butte: Montana Bureau of Mines and Geology.

Butte Water Company, 1994. 1993 Annual Report of the Butte Water Company. Report to the Montana Public Service Commission.

Butte Water Company, 1995. Data on use per metered hookup for 1994.

Colander, David Charles and John C. Haltiwanger. 1979. "Comment on 'Price Elasticity of Demand for Municipal Water: A Case Study of Tucson, Arizona' by Robert Young" Water Resources Research vol. 15 no. 5

Desvousges, William H. and Steven M. Waters. 1995. Appendix D to: Volume III. Report on Potential Economic Losses Associated with Recreation Services in the Upper Clark Fork River Basin. Expert Report in State of Montana v. Atlantic Richfield Company.

Desvousges, William H. 1995a. Volume IV. Critique of the State of Montana's Groundwater Valuation. Expert Report in State of Montana v. Atlantic Richfield Company.

Desvousges, William H. 1995b. Volume V. Report on Potential Economic Losses Associated with Groundwater. Expert Report in State of Montana v. Atlantic Richfield Company.

Danielson, Leon. 1977. "Estimation of Residential Water." Economics Research Report no. 39. North Carolina State Univ. at Raleigh,. 1977.

Duaime, Ted and John Metesh. 1995. "Rebuttal to 'ARCO's Groundwater Injury Reports' by Remy J-C. Hennet and Steven P. Larson." Prepared for Montana Natural Resource Damage Litigation Program, Department of Justice, Helena, Montana.

Duffield, John W., Chris Neher, Mark Josephson and Richard Josephson. 1991. "Market Value of Agricultural Water Leased for Instream Flows." Report to Montana Department of Fish, Wildlife and Parks.

Gibbons, Diana C. 1986. The Economic Value of Water A Study from *Resources for the Future*, Washington D.C.

Hieger, Jennifer. "Water: Micron wants right kind, plenty of it, but where in Butte will it come from?" The Montana Standard January 29, 1995.

Howe, Charles W. and F. P. Linaweaver, Jr. 1970. "The Impact of Price on Residential Water Demand and Its Relation to the System Design and Price Structure" Water Resources Research vol. 5 no. 1.

James M. Montgomery Consulting Engineers, Inc. 1988. Butte Water System Master Plan. Report to Butte-Silver Bow Government and Butte Water Company.

Maest, Ann S., John J. Metesh, and Richard J. Brand. January 1995. "Butte Groundwater Injury Assessment Report, Clark Fork River Basin NPL Sites, Montana." Prepared for Montana Natural Resources Damage Litigation Program, Department of Justice, Helena, Montana.

Meinzer, O.E. 1914. The Water Resources of Butte, Montana. U.S. Geological Survey Water-Supply Paper 345-G, p. 79-125.

Metesh, John J. April 1993. "Montana Pole Treatment Plant Groundwater Injury Assessment, Butte, Montana." Prepared for Montana Natural Resource Damage Litigation Program, Department of Justice, Helena, Montana. 64 p.

Metesh, John J. 1995. Deposition of John Joseph Metesh in Montana v. ARCO, Volumes I-III, Examination date: April 5-7, 1995.

Montana Agricultural Statistics Service. 1982-1994. "Montana Agricultural Statistics: County Statistics." Helena, Montana.

Montana Department of Health and Environmental Sciences. June 1994. "Montana Water Quality 1994: The Montana 305(b) Report." Helena, Montana. 159 pp.

Montana Department of Natural Resources and Conservation. 1988. "Draft Environmental Impact Statement for Water Reservation Applications in the Upper Clark Fork Basin." Helena, Montana. 171 pp.

Montana Department of Natural Resources and Conservation. 1992. " Missouri River Basin Final Environmental Impact Statement for Water Reservation Applications above the Fort Peck Dam."

Montana Natural Resource Damage Litigation Program. May, 1993. "Summary and Overview: Groundwater Injury Assessment Reports Clark Fork River Basin Montana".

Office of Management and Budget Circular A-94, "Guideline and Discount Rates for Benefit-Cost Analysis of Federal Programs" November 3, 1992.

Renzetti, Steven. 1992. "Evaluating the Welfare Effects of Reforming Municipal Water Prices." Journal of Environmental Economics and Management 22, p. 147-163

Robert Peccia & Associates, "Anaconda Water Systems Improvements Program" Helena, MT.

Robert Peccia & Associates, 1991. "Butte Water System Three Year Improvements Program 1992-94." Helena, MT.

Saliba, Bonnie C., David B. Bush, William E. Martin, and Thomas C. Brown. 1987. "Water Marketing in the Southwest -- Can Market Prices Be Used to Evaluate Water Supply Augmentation Projects?" United States Department of Agriculture, Forest Service. General. Technical Report RM-144.

State of Montana, October, 1995. "Restoration Determination Plan for the Upper Clark Fork Basin." Helena: Montana.

USDA Soil Conservation Service. Montana Irrigation Manual . USDA Soil Conservation Service. Bozeman, MT.

Woessner, William W. January 1995a. "Anaconda Groundwater Injury Assessment Report." Prepared for Montana Natural Resource Damage Litigation Program, Department of Justice, Helena, Montana. 203 pp.

Woessner, William W. January 1995b. "Milltown Groundwater Injury Assessment Report." Prepared for Montana Natural Resource Damage Litigation Program, Department of Justice, Helena, Montana. 130 pp.

Woessner, William W. January 1995c. "Rocker Groundwater Injury Assessment Report." Prepared for Montana Natural Resource Damage Litigation Program, Department of Justice, Helena, Montana. 59 pp.

Wong, S. T. 1992. "A Model on Municipal Water Demand: A Case Study of Northeastern Illinois." Land Economics vol. 48, no 1, p. 34

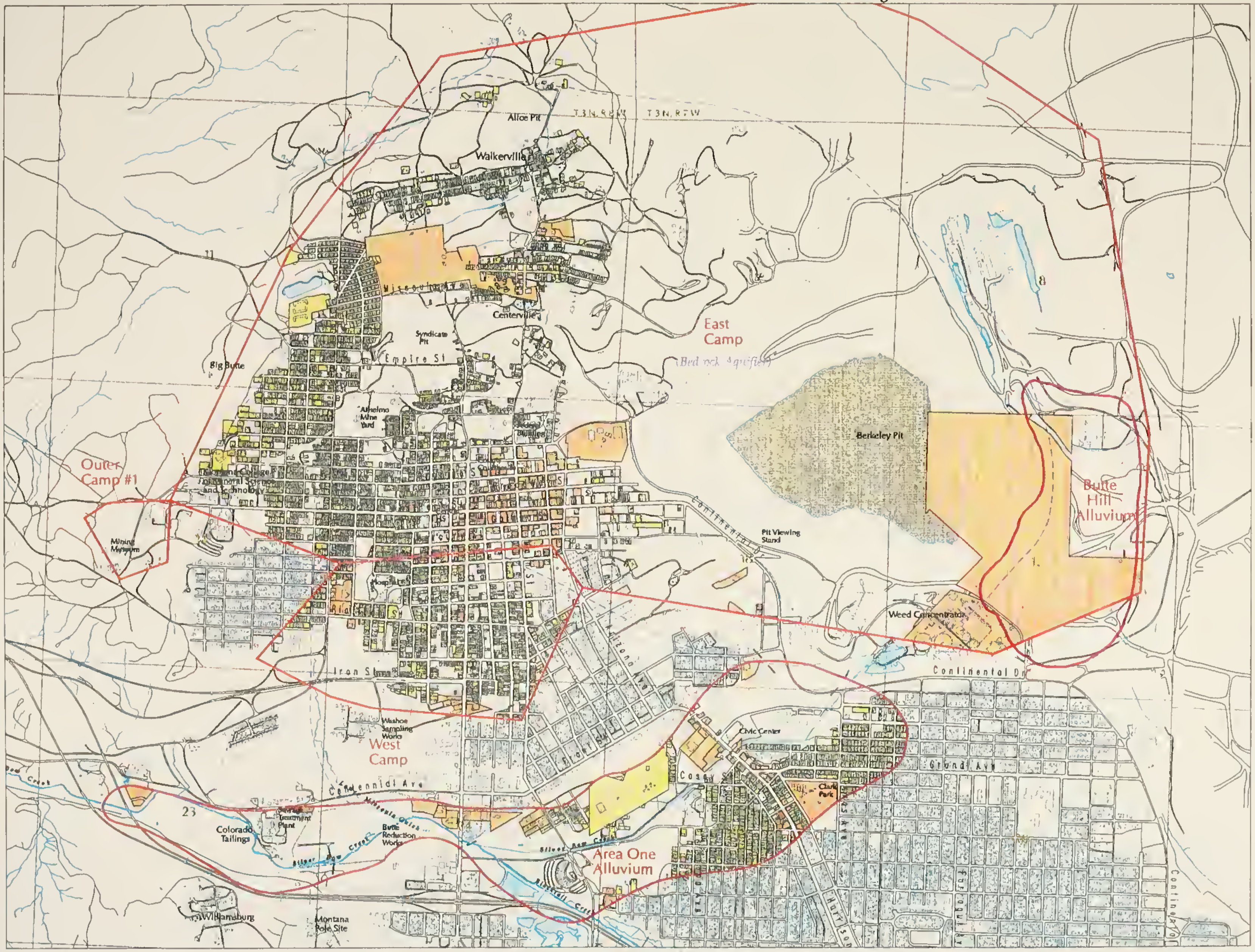
Young, Robert A. 1973. "Price Elasticity of Demand for Municipal Water: A Case Study of Tucson, Arizona" Water Resources Research vol. 9 no. 4

Young, Robert A., S. Lee Gray, R. Burnell Held and Richard S. Mack. 1972. "Economic Value of Water: Concepts and Empirical Estimates" Final Report to the National Water Commission. Department of Economics, Colorado State University, Fort Collins, CO

# Appendix A: Butte-Silver Bow GIS Map of Area of Contamination and Description of Number of Households and Businesses in the Affected Area.

## Groundwater Contamination in Butte, Montana

State of Montana Natural Resources Damage Claim



Disk3/butte/health/h2oqual/maps/26795.aml Printing date is 11/02/95

### Legend

- Boundary of Alluvium or Underground Mineworkings
- Boundaries From Original Analysis
- Street or Road
- Hydrologic Feature
- Building or Structure
- Section Line
- 🟨 Parcel-Residence
- 🟧 Parcel-Commercial Business
- 🟦 Pond or Containment

Source for Area One Alluvium:
1)Natural Resource Damage Assessment for Butte
RCG Hagler & Bailey, Inc;
2)Phase II Remedial Investigation by CH2M Hill, f
State of Montana.

Source for Underground Mine Workings (Areas kn
as East Camp, West Camp and Outer Camp #1):
John Metesh, for Natural Resource Damage Assess
Based on outermost extent of mineshafts.

Source for Residential and Commercial Lots:
Montana Department of Revenue CAMA Data for
the Butte Silver Bow Appraiser's Office.

Source for Planimetrics:
1989 and 1991 Horizon, Inc Aerial Photography

# Memorandum

**DATE:** October 4, 1995

**TO:** Greg Mullen

**FROM:** Tom Tully, BSB GIS

RECEIVED
OCT 0 5 1995
NATURAL RESOURCE
DAMAGE PROGRAM

**RE:** Analysis of number of residences and businesses for NRDC

Greg,

This explains how I queried our data to find out the number of residences and commercial bldgs in the West Camp, East Camp, Outer Camp #1, and Area One Alluvium areas of Butte.

I used John Metesh's projections of the extent of the underground workings instead of the original Contaminated Aquifers map that we used initially, and Area One Alluvium.
Metesh's boundaries were determined using mineshaft locations for point to point delineations, thus do not actually show the furthest extent of the underground workings.

1)Select from Montana Department of Revenue CAMAS data all common CAMA parcels containing a dwelling or mobile home. This query yields 3218 parcels.

2)Then select from the CAMAS data commercial parcels that are coded as having a domicile on the premises. At this point there are 3649 parcels that are coded as being residences.

3)Finally, the commercial CAMAS parcels were queried to determine the number of commercial buildings that are not residential properties.
This query yields 396 parcels.

Residential Parcels: 3649
Commercial Parcels: 396

The discrepancy between the number of residences from a year ago and this recent analysis resulted from not dropping out commercial vacant lots when querying the commercial data for a domicile on premise, thus giving an inflated number. (Though as it turns out the total, using a slightly different analysis method, is not far from the original, especially when adding in the commercial parcels with a residence.)

I would recommend deflating the totals for both residential and commercial by a factor of 5%, as there is some inflation of the numbers because of inherent peculiarities within the GIS data.

# Appendix B: Description of Implementation and Results of Butte Groundwater Survey

## 1.0 Purpose of Survey

The Butte Groundwater Survey was undertaken as a supplement to survey information gathered by Desvousges (1995b) in his Montana Water Quality Survey. Desvousges (1995b) asked respondents whether they would prefer to be on a private well or the Butte municipal water system if the costs and quality of the two systems were the same. In fact, in the absence of contamination neither the costs nor the quality of a private well system would be the same as those of the Butte system; private well water would be cheaper and substantially better than the municipal water. Desvousges' analysis confirms this when he calculates private well costs which are roughly one-half of municipal water costs, and when he estimates substantial costs associated with averting behaviors taken by Butte residents. The Butte Groundwater survey was undertaken to ascertain the percentage of Butte residents living over the contaminated aquifer who would prefer to use a private well as a water source given the true comparison between the two alternative sources regarding cost and quality.

## 2.0 Development of Questionnaire

The questionnaire used in the Butte Groundwater Survey followed closely the wording used by Desvousges (1995b) in his Montana Water Quality Survey. The Desvousges (1995b) questionnaire was extensively pretested and reviewed through focus groups, pretests, and peer review (Desvousges, 1995b - Appendix A). The Butte Groundwater Survey was based on sections of the Desvousges (1995b) survey and was minimally modified. The survey instrument was peer reviewed by Dr. David Patterson of the University of Montana Department of Mathematics and on October 4, 1995 the survey was pretested by Responsive Management. The pretest implementation was monitored by Mark Duda of Responsive Management. A small number of pretests were administered with 8 surveys completed to see if the survey wording and structure were workable. As a result of the pretest, a final set of possible respondent questions and appropriate answers were developed to be given to Responsive Management's survey agents. A copy of these questions and answers is contained in Attachment B-3. No changes to the actual survey structure and questions were made as a result of the pretest.

## 3.0 Content of the Survey Questionnaire

The survey instrument itself (see attachment B-1) asked a handful of demographic questions, a few questions on problems municipal water users have experienced with their water, and questions on municipal water users' preference for using a private well or the Butte municipal system. Potential respondents received a contact letter on October 4 which explained the purpose of the survey and advised residents they would be contacted (see attachment B-2).

## 4.0 Description of Sample Frame

A sample of Butte households was drawn from all households listed in the Butte telephone directory residing in an area overlying the area of groundwater contamination. The sample was drawn by Survey Sampling Incorporated (SSI) of Fairfield, Connecticut (see attachment

B-4 for the Survey Sampling, Inc. definition of the sample drawn). The smallest sampling block from which SSI could draw was the census block group level. Census block groups were defined for all contaminated areas of the city. These block groups included all of census tract number 1 with the exception of block groups 1 and 2, census tract 2 block groups 1,2,3,5,6, and 7, census tract 3 block group 1, census tract 4 block groups 5 and 6, and census tract 8 block group 1. Ten replicates of 100 phone numbers each were drawn as a sample base for the survey. It was necessary to use only 8 replicates to reach the target of 400 completed surveys. The census tracts and block groups correspond closely to the area of contamination with some edges of selected block groups lying just outside of the defined boundary of contamination.

## 5.0 Survey Implementation

### 5.1 Sample Size and Response Rate

The telephone survey was implemented on October 4, 5, 6, and 7, 1995 by Responsive Management of Harrisonburg, VA. Out of a total sample of 741 phone numbers, 59 were disconnected, 12 were businesses, and 64 were non-working numbers. The pool of potential respondents was, therefore, 606 numbers. Of these 606 numbers, 410 completed interviews, 44 refused interviews, 5 terminated the interview, 4 had language barriers, and 143 were answering machines or non-completed call-backs. The overall response rate for the survey was 68% to 90% depending on the treatment of non-completed call-backs (Table B.1). This compares to the reported response rates of 60% to 66% for Desvousges (1995b).

**Table B.1. Comparison of response rates of Desvousges' (1995b) survey and the Butte groundwater Survey.**

| Category / statistic | Desvousges | Current survey |
|---|---|---|
| (A) Eligible sample | 665 | 606 |
| (B) Refusals | 208 | 49 |
| (C) Unable to Contacts (UTC) and incapables | 61 | 147 |
| (D) Completed Interviews | 396 | 410 |
| Hard refusal rate | 31% | 8% |
| Response rate counting all UTC's and incapables as refusals (D-A) | 60% | 68% |
| Response rate counting all UTC's and incapables as ineligible (D/(A-C)) | 66% | 89% |
| Response rate counting same proportion of UTC's and ineligibles as refusals (D+C*(1-(B/A))/A) | 66% | 90% |

## 5.2 Data Entry Procedures and Quality Control

Survey agents from Responsive Management entered respondents' answers to survey questions directly into a computer data base. The direct entry of data reduces problems associated with translating of handwritten responses into a database. The completed database was examined for typographic errors and was delivered via Federal Express to Bioeconomics, Inc on October 11, 1995.

## 6.0 Data Evaluation

In evaluating responses to the Butte Groundwater Survey, Bioeconomics, Inc. produced frequency distributions and mean values for all of the questions in the survey. These statistics were then studied in order to 1) check for extreme values, 2) evaluate the reliability of the answers, and 3) identify missing responses.

In evaluating the reliability of the answers, the answers to the primary survey question on respondent's preference for private well or municipal water were compared to their verbal reasons given for this choice. Respondents' stated preferences made sense in comparison to the given reason for the choice. No modifications were made to the data based on this evaluation (see attachment B-5 for a listing of reasons given for water source preference).

In investigating extreme values, all responses were plausible and no modifications were made to the data.

Missing responses in the data were left missing, and thus excluded from analysis. No attempt was made to impute a substitute value in these cases.

## 7.0 Results

The primary result from the Butte Groundwater Survey was an estimate of the percentage of residential households and individuals owning residential rental property who would prefer to be on a private well rather than the Butte municipal system given the cost and quality differentials between uncontaminated groundwater and the current and historical Butte municipal water system.

Of the 410 households contacted, 399 were asked their preference of water source and 219, or 54.9% stated they would prefer to be on a private well. Of the 43 individuals who owned residential rental property in Butte 17 or 39.5% said they would prefer to provide water to their rental properties from a private well.

On the issue of municipal water quality, 82% of respondents said they had experienced dirty or discolored water in the past. When asked whether they had ever noticed their tap water smelling or tasting bad, 71.9% responded yes. Finally, 87.2% said they had been aware of tapwater "boil orders" in the past.

## 8.0 Comparison to the results of the Montana Water Quality Survey

Most of the questions asked in the Butte Groundwater Survey were also asked by Desvousges (1995b) in the Montana Water Quality Survey. There were many similarities between responses to the two surveys. Table B.2 shows comparisons of selected question responses from the two surveys.

**Table B.2. Comparison of responses between Desvousges' (1995b) survey and the Butte Groundwater Survey**

| Question | Butte Groundwater Survey | Desvousges' (1995b) Montana Water Quality Survey |
|---|---|---|
| Number of years lived in Butte | 37.14 | 34.72 |
| Number of years lived at current address | 18.27 | 19.5 |
| Percent homeowners | 78.8% | 75.9% |
| Percent who had experienced dirty or discolored tap water | 82.0% | 73.4% |
| Percent who were aware of a "boil order" | 87.2% | 64.6% |

As Table B.2 shows, responses to similar questions in the two surveys are, in many instances, quite close. Respondents to the Butte Groundwater Survey reported a higher proportion of problems with dirty water and boil orders. In fact, nearly 100% of respondents should have received "boil orders" from the Butte municipal system in recent years, so on these questions it appears that the responses to the Butte Groundwater Survey more closely track reality than do responses to Desvousges' survey.

Not surprisingly, a higher proportion of respondents to the Butte Groundwater Survey said they would rather be on a private well than the Butte municipal system in the absence of groundwater contamination. This was expected as respondents to this survey were asked their preferences under the conditions that ground water would be cheaper and of better quality, and respondents to Desvousges' survey were asked their preference under conditions of equal cost and quality. Table B.3 shows a comparison of responses to the water source question between the Desvousges study and the Butte Groundwater Survey. It should be noted that the estimate of 54.9% of respondents preferring a private well is conservative. Examination of the reasons given for this preference (attachment B-5) show that a number of respondents rejected the scenario given and said that they could not have a well because of either the citywide moratorium on well construction or the fact that mining had contaminated the groundwater. Had these respondents accepted the stated scenario of clean, uninjured groundwater and no moratorium on well construction, a portion of these respondents may well have stated a preference for a private well.

**Table B.3. Comparison of percentage of respondents preferring a private well between Desvousges (1995b) and current study**

| Prefer: | What if same quality and cost[a] | | What if well cheaper and better quality[b] | |
|---|---|---|---|---|
| | n | % | n | % |
| (A) Well | 114 | 33.9 | 219 | 54.9 |
| (B) Public water supply | 205 | 60.5 | 123 | 30.8 |
| (C) No preference | 10 | 2.9 | 15 | 1.3 |
| (D) Depends on ... | 3 | 0.9 | 17 | 4.3 |
| (E) Don't know | | | 35 | 8.8 |
| (F) Total sample who answered question | 339 | 100.0 | 399 | 100.0 |
| Missing | 57 | | 11 | |

[a] Desvousges (1995b), complete sample

[b] Bioeconomics (1995), complete sample

## Attachment B-1: Butte Groundwater Survey, Survey Instrument

Bioeconomics, Inc: Butte Water Quality Survey
Responsive Management

1. PRESS RETURN WHEN SOMEONE ANSWERS

TIMER STARTS AFTER THIS SCREEN

2. Time when interview began

1:1-5

☐☐☐☐☐

3. Hello, my name is ---------, and I'm calling on behalf of Bioeconomics in Missoula. We are conducting a survey concerning Butte drinking water. We are not selling anything; we simply need your opinions and it will only take a few minutes.

I would like to speak with an adult male or female head of your household who is most familiar with the quality and cost of your household's drinking water. Is one of those people available?

1:6

(CHECK ONLY ONE ANSWER)

☐ 1. Correct person: start survey (GO TO QUESTION 6)

☐ 2. Schedule recall (CB) (GO TO QUESTION 4)
☐ 3. Answering Machine (GO TO QUESTION 5)
☐ 4. RF, BG, DL

SKIP TO QUESTION 30

---

4. When would be the best time for me to call back? Thank you for your time.

ENTER DAY/TIME ON CALL SHEET (CB)

SKIP TO QUESTION 30

---

5. LEAVE FOLLOWING MESSAGE ON ANSWERING MACHINE:
Hello, my name is ---------, and I'm calling for Bioeconomics in Butte. We're doing a survey about water quality. We will try to call back in the near future. Thank you.

PRESS RETURN TO CONTINUE
SKIP TO QUESTION 30

===========================================================

6. First I'm going to ask you some questions about your household's tap water. Please keep in mind that these questions are referring to the tap water used at your current residence.

Does your tap water come from the Butte municipal water supply, a private well, or some other source?

1:7

(CHECK ONLY ONE ANSWER)

☐ 1. Butte municipal water supply
☐ 2. Private well (GO TO QUESTION 18)
☐ 3. Other (GO TO QUESTION 7)
☐ 4. Don't know

SKIP TO QUESTION 8

===========================================================

7. ENTER HERE WHERE HOUSEHOLD WATER SUPPLY COMES FROM:

2:1-120

8. Have you ever had any problems with dirty or discolored tap water?

3:1

(CHECK ONLY ONE ANSWER)

☐ 1. Yes
☐ 2. No
☐ 3. Don't know

9. Have you ever noticed your tap water smelling or tasting bad?

3:2

(CHECK ONLY ONE ANSWER)

☐ 1. Yes
☐ 2. No
☐ 3. Don't know

10. Have you ever received a "boil order" for your tap water?

3:3

(CHECK ONLY ONE ANSWER)

☐ 1. Yes
☐ 2. No
☐ 3. Don't know

11. OK, now I'd like to ask you what type of water source you would prefer for your household, but first I need to know if you own any residential rental property in Butte.

3:4

(CHECK ONLY ONE ANSWER)

☐ 1. Yes
☐ 2. No

12. Suppose your household had a choice between being on a private well or the Butte municipal water system for your tap water. Say the water from the private well would be of better quality, as well as less expensive in the long run than the Butte water system. Which system would your household prefer, given these conditions?

3:5

(CHECK ONLY ONE ANSWER)

☐ 1. Private well (GO TO QUESTION 14)
☐ 2. Municipal water system (GO TO QUESTION 14)
☐ 3. It depends on... (GO TO QUESTION 13)
☐ 4. No preference
☐ 5. Don't know

IF (#11 = 1) GO TO #15
IF (#11 = 2) GO TO #17
IF (#11 = 1) GO TO #15
IF (#11 = 2) GO TO #17

13. (ENTER HERE WHAT IT DEPENDS ON)

4:1-120

IF (#11 = 2) GO TO #17

SKIP TO QUESTION 15

14. What is the main reason your household would prefer this system?

5:1-120

IF (#11 = 2) GO TO #17

15. Under the same conditions as in my last question about the water systems, would you rather use a private well or the Butte water system for your rental property?

6:1

(CHECK ONLY ONE ANSWER)

☐ 1. Private well
☐ 2. Municipal water system
☐ 3. No preference
☐ 4. Depends on... (GO TO QUESTION 16)
☐ 5. Don't know

SKIP TO QUESTION 17

16. (ENTER HERE WHAT IT DEPENDS ON)

7:1-120

17. OK, we're almost through. The last few questions are for background information to help us analyze the results.

PRESS RETURN TO CONTINUE

18. How long have you lived in Butte?

(ENTER NUMBER OF YEARS;
IF LESS THAN ONE YEAR, ENTER 1)

8:1-2

|__|__|

19. How long have you lived at your current address?

(ENTER NUMBER OF YEARS)

8:3-4

|__|__|

20. Do you rent or own at this address?

8:5

(CHECK ONLY ONE ANSWER)

☐ 1. Rent
☐ 2. Own
☐ 3. Other (GO TO QUESTION 21)
☐ 4. Don't know

SKIP TO QUESTION 22

---

21. (ENTER 'OTHER' ANSWER HERE)

9:1-120

________________________________________

________________________________________

________________________________________

22. Which of the following categories best describes your total household income before taxes from all sources in 1994?

10:1

(CHECK ONLY ONE ANSWER)

☐ 1. Less than $10,000
☐ 2. $10,000 to $19,999
☐ 3. $20,000 to $29,999
☐ 4. $30,000 to $49,999
☐ 5. $50,000 to $74,999
☐ 6. $75,000 or more
☐ 7. DNR: Refused

23. May I ask your age?

10:2-3

☐☐

24. Finally, have you participated in a survey of your household water use in Butte in the past year?

10:4

(CHECK ONLY ONE ANSWER)

☐ 1. Yes
☐ 2. No

25. Great, that's the end of the survey. Thank you very much for your help.

(ENTER ANY COMMENTS HERE)

11:1-120

________________________________________

________________________________________

________________________________________

26. OBSERVE AND RECORD GENDER

12:1

(CHECK ONLY ONE ANSWER)

☐ 1. Don't know
☐ 2. Male
☐ 3. Female

27. Time interview was completed

12:2-6 |__|__|__|__|__|

28. PLEASE ENTER YOUR INITIALS.

12:7-9 |__|__|__|

29. ENTER TELEPHONE NUMBER OFF CALL SHEET.

12:10-19 |__|__|__|-|__|__|__|-|__|__|__|__|

30. SAVE OR ERASE THE INTERVIEW.
ONLY ERASE IF: Terminated, Refused, Busy, No Answer, Number Out of Service, Business, Fax, Language barrier, Answering machine

12:20 (CHECK ONLY ONE ANSWER)

☐ 1. Save answers (GO TO QUESTION 32)
☐ 2. Erase answers
☐ 3. Review answers (GO TO QUESTION 6)

31. ARE YOU SURE YOU WANT TO ERASE THIS INTERVIEW?
ONLY ERASE IF: Terminated, Refused, Busy, No Answer, Number Out of Service, Business, Fax, Language barrier, Answering machine

12:21 (CHECK ONLY ONE ANSWER)

☐ 1. No, do not erase the answers (GO TO QUESTION 30)

☐ 2. Yes, erase this interview

32. Date interview was completed

12:22-27 19|__|__|-|__|__|-|__|__|
Year Month Day

SAVE IF (#30 = 1)

## Attachment B-2: Respondent Contact Letter

BIOECONOMICS INC.
3699 Larch Camp Road • Missoula, Montana 59803 • (406) 721-5511

September 19, 1995

Dear Butte Resident,

Your household has been randomly selected to participate in a brief survey concerning drinking water in the city of Butte. The survey questions will take less than 5 minutes to answer. We are interested in your opinions on Butte water quality and water use in your home. This study is being done for scientific purposes, and we are not trying to sell you anything. In order for our results to be representative it is very important that someone from your home participate.

You will receive a call from us in the next week. When we call we will ask to speak to a male or female head of your household who is familiar with the quality and cost of your household's drinking water. If we call at an inconvenient time, please let our survey agent know when would be a good time to call back.

I would like to stress how important it is for your household to participate in this brief survey. I would like to also thank you in advance for your help.

Sincerely,

Chris Neher
Survey Manager

## Attachment B-3. Survey Agent Possible Respondent Questions and Appropriate Answers

# Some Possible Respondent Questions and Appropriate Answers

1. Q. Who is Bioeconomics?

   A. Bioeconomics is a Missoula-based economic research firm. Much of the research conducted by Bioeconomics focuses on Montana environmental issues.

2. Q. What if I don't want to answer a specific question?

   A. We can skip any question which you feel uncomfortable answering.

3. Q. What will my responses be used for?

   A. Your answers will be combined with those of other survey respondents from Butte to help Bioeconomics better understand the issue of household water use in the Butte Area.

4. Q. Who is sponsoring this study?

   A. In order not to bias your responses, I was not told who the survey sponsor is.

5. Q. What do I need to know in order to answer the questions?

   A. The survey asks a very few basic questions about where your household's tap water comes from and what the quality of that water has been in the past.

6. Q. Will my responses be confidential?

   A. While we cannot guarantee that your responses will be confidential, we can assure you that they will only be used for examining the issue of Butte water use. We can assure you that your name will not be placed on any mailing lists.

7. Q. Are you interested in tap water problems that occurred several years ago?

   A. Yes. For these questions, please think back over the past 10 years and include any tap water problems you have experienced in that time.

8. Q. This question (Q8 or Q11) doesn't make sense. We are required to be on the Butte water system. We don't have the choice to drill a well.

   A. For this question please assume that YOU DO HAVE THE CHOICE to install a private well.

9. Q. I couldn't drill a well because the (mine / contamination / tailings) makes the water undrinkable.

   A. For this question, please assume that the groundwater under your home is clean and unaffected by any mining activities.

10. Q. How much better would the well water be than the Butte municipal water?
A. Please assume that the well water would be the quality of uncontaminated spring water.

11. Q. How much cheaper would the well water be than the Butte municipal water?
A. Over the life of the well, the well water would cost roughly 1/2 of what Butte municipal water would cost.

12. Q. What do you mean it would be cheaper over the long run?
A. Over the long run means that your average yearly costs of well water over the useful life of the well would be significantly lower than the yearly cost of Butte municipal water over the same period.

13. Q. What do you mean by the "long Run"?
A. The long run means the useful life of the well. The average well has a useful life of 50 years.

14. Q. How can I be sure this is really a survey?
A. I would be glad to give you the name of the survey manager: His name is Chris Neher and he can be reached during working hours at Bioeconomics in Missoula. His phone number is 721-2265.

15. Q. What do you mean by EVER, as in "have you ever received a boil order"?
A. Please think back over the past 10 years. In that time have you been aware of a "boil order " for your water?

## Attachment B-4. Survey Sampling, Inc. Description of Sample Frame

Survey Sampling, Inc.
Fairfield, CT (203) 255-4200
Report Date : 21-SEP-95
SSI Order # : 083998.001

Company Name : Bioeconomics
Client Order : Butte Ground Water Stdy
Sample Name : Selected Tracts/BG's

## Sample Specification Report

**Please review this specification report carefully to ensure the contents of this order are correct. We have checked the specifications as we understand them but the ultimate responsibility to ensure that the sample properly represents the Client's Specifications is that of the Client.**

If any changes need to be made, please call Debbie Walter.

Client Contact: Chris Neher

Ship Date : 21-Sep-19
Order Date : 21-Sep-19

Listed Sample
=============

Sample Type : Panel
Sampling Frame: Panel

Sample Size : 1,000
Screening Option: No

Record Types : Directory Listed Only

Number of Replicates: 10
Starting Replicate : 001

NO Demographic selections requested

Geographic Selection:

| Include Geography: | User Quota: | Mkt/Region Code: |
|---|---|---|

==================

Census Tract

Market Input File : TRCT083631.001M

000100 30093 - SILVER BOW, MT

Census Block Group

Market Input File : BG083631.001M

30093 000200 1
30093 000200 2
30093 000200 3
30093 000200 5
30093 000200 6
30093 000200 7
30093 000300 1
30093 000400 5
30093 000400 6

```
                                          Page           :    2
Survey Sampling, Inc.                     Company Name   : Bioeconomics
Fairfield, CT  (203) 255-4200             Client Order   : Butte Ground Water Stdy
Report Date  : 21-SEP-95                  Sample Name    : Selected Tracts/BG's
SSI Order #  : 083998.001

                      Sample Specification Report


30093  000800 1

  Exclude Geography:
  ==================

Census Block Group

Market Input File : BG083631.001E

30093  000100 1
30093  000100 2
                                                        Label:  Tract
Keyline Items : Census Tract

Output Sort    : Replicate Number or Group Code
                 Sub-Replicate Number
                 Time Zone
                 Area Code
                 Exchange
                 Phone Number - 4 digits

 Delivery Information:             Data Items:
 Method:                           Phone Number - Print Formatted
   Print 1 Copy                    Name Field
   1 per page                      Address - Line 1
                                   City, State, ZIP Code
                                   Keyline Header
                                   14 Byte Keyline

                                   Name Field
   Print 1 Copy                    Address - Line 1
   Labels                          City, State, ZIP Code

                                   DIR$PD:NADR_PHONE.RECORD
   Diskette                        Area Code
                                   Exchange
                                   Phone Number - 4 digits
                                   Time Zone
                                   Replicate Number or Group Code
                                   Sub-Replicate Number
                                   14 Byte Keyline
                                   Name Field
                                   Address - Line 1
                                   Fielded City
                                   Fielded State
                                   ZIP Code
```

Survey Sampling, Inc.
Fairfield, CT (203) 255-4200
Report Date : 21-SEP-95
SSI Order # : 083998.001

Page : 3
Company Name : Bioeconomics
Client Order : Butte Ground Water Stdy
Sample Name : Selected Tracts/BG's

## Sample Specification Report

No RESULT CODES requested
No TITLES requested

In accepting this shipment the user agrees to the following terms and conditions,

1. All samples developed by SSI for CLIENT remain the sole property of SSI and are to be used by CLIENT only for the purposes of conducting survey research. CLIENT agrees not to use any information contained in an SSI sample to generate additional samples. In the event of misuse of SSI samples by CLIENT or its employees, agents, or suppliers, CLIENT agrees to reimburse SSI five times the original price of the sample(s) so misused.

2. SSI is not responsible for any delays once a sample has left SSI's possession. In the event of any claim, action or proceeding by CLIENT against SSI as a result of any breach of the Agreement, or in any way related to this Agreement, directly or indirectly, the loss, liability, damage, or expense alleged by the CLIENT shall not exceed in the aggregate the amount paid by CLIENT to SSI for the right to use the particular sample in question, irrespective of the breach, cause or circumstances which may be alleged or proved.

## Attachment B-5. Reasons for Water Source Preference as Given by Respondents

The listed reasons on the following pages were given in response to the question: "What is the main reason your household would prefer this system?" (The system being either a private water well or water from the municipal system.) The reasons given are sorted by the water source preferred by the respondent. First are listed the reasons given by those who preferred a private well; following this are the reasons for those preferring the existing Butte municipal system.

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                    Bioeconomics, Inc: Butte Water Quality Survey
                                Responsive Management

------------ Suppose your household had a choice betw=Private well ------------

WHYSTR

BECAUSE THE WATER IS BETTER
ECONOMIC REASONS AND BETTER WATER
BETTER QUALITY WATER
QUALITY OF THE WATER IS BETTER
BETTER QUALITY WATER
QUALITY OF WATER
BETTER WATER AND CHEAPER
CLEANER WATER AND LESS CHLORINE
QUALITY OF THE WATER WOULD BE BETTER
TASTE BETTER AND THERE WOULD BE LESS PROBLEMS AND CHEAPER
BETTER QUALITY
QUALITY IS BETTER
TASTE OF WATER
BECAUSE HE DOES NOT LIKE THE WATER
BETTER WATER
BETTER QUALITY, CHEAPER
WELL WATER IS JUST BETTER
BETTER QUALITY WATER
CHEAPER AND BETTER QUALITY WATER
BETTER
BETTER QUALITY OF WATER
QUALITY OF THE WATER
QUALITY OF WATER
BETTER TASTE
MORE CONSISTENT WATER QUALITY
WELLS HAVE BETTER WATER
BOTH RAISED WITH WELLS, I AM AFRAID OF BUTTE MUNICIPAL WATER EVEN THOUGH WE HA
BETTER QUALITY, NO MORE BUYING BOTTLED WATER
THEN YOU DON'T HAVE TO PAY FOR IT ITS A ONE SHOT DEAL
PURER WATER
CHEAPER
BETTER WATER
CLEANER WATER.
BUTTE WATER SUCKS.
BECAUSE ITS CHEAPER AND CLEANER.
BETTER TASTING AND CHEAPER.
IT WOULD BE BETTER AND CHEAPER.
THE WATER WOULD BE SAFER.
BETTER QUALITY WATER.
BETTER QUALITY.
I'M TIRED OF PAYING SO MUCH FOR WATER THAT I CAN'T EVEN USE.
ITS BETTER FOR YOU.
BETTER QUALITY AND COST.
YOU CAN DRINK IT.
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                    Bioeconomics, Inc: Butte Water Quality Survey
                               Responsive Management

------------ Suppose your household had a choice betw=Private well ------------
                                    (continued)

WHYSTR

THE WATER IS PURE AND SANITARY.
IF IT WERE CHEAPER I'D PREFER IT.
BETTER QUALITY AND LESS CHEMICALS.
WELL WATER TASTES BETTER.
CLEANER
PRICE
BUTTE MUNICIPAL WATER AUTHORITY MAKES RESIDENTS PAY A FLAT RATE ON SUMMER WATE
TROUBLE WITH BUTTE WATER
BETTER WATER
ECONOMICS
ALWAYS HAD ONE IN THE PAST
DON'T DRINK BUTTE WATER
CLEANER WATER
EXPERIENCE WITH PEOPLE WITH WELLS
BETTER WATER
I'M GETTING CHARGED FOR SHIT THAT AIN'T WORTH A DAMN
TASTE
BETTER QUALITY
CLEANER AND HEALTHIER
BETTER WATER
BUTTE WATER IS TERRIBLE
QUALITY
COST AND QUALITY, BUTTE HAS VERY BAD WATER QUALITY
BETTER WATER
CAN'T DRINK BUTTE WATER
BETTER WATER
COST AND BETTER QUALITY
THE QUALITY OF WATER.
YOU CAN DRINK WELL WATER, WHILE YOU CAN'T DRINK BUTTE WATER.
THE MAIN REASON WOULD BE TO HAVE CHEAPER AND BETTER WATER.
THE PURE WATER.
I THINK THE WATER WOULD BE BETTER.
BECAUSE IT IS BETTER WATER.
BETTER WATER QUALITY.
IF THE WATER QUALITY WOULD BE BETTER, I WOULD WANT IT.
I GREW UP WITH A WELL AND IT IS MUCH BETTER.
BECAUSE IT IS CHEAPER AND BETTER WATER.
IF IT WAS CHEAPER AND CLEANER, I WOULD WANT IT.
THE EXPENSE.
BECAUSE OF THE PRICE AND QUALITY OF THE WATER.
BECAUSE THERE HAVE BEEN SO MANY PROBLEMS WITH THE BUTTE WATER SYSTEM.
FOR BETTER WATER QUALITY.
IT IS
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          Bioeconomics, Inc: Butte Water Quality Survey
                     Responsive Management

------------ Suppose your household had a choice betw=Private well -------------
                          (continued)

WHYSTR

 WANT GOOD WATER
YOU JUST TOLD ME THAT IT IS BETTER
FOR THE REASONS YOU JUST GAVE ME. WHO DOESN'T WANT BETTER DRINKING WATER?
 WOULD LIKE TO BE ABLE TO DRINK MY TAP WATER WITHOUT IT MAKING ME SICK.
BETTER WATER
WE WOULD HAVE INDEPENDANT CONTROL OVER IT
IF IT WAS BETTER AND CHEAPER OF COURSE I'D TAKE THE WELL
THERE WOULD BE NO CHLORINE
I'M NOT CONVINCED THAT THEY (BUTTE) HAVE THE ABILITY TO GET ALL OF THE IMPURITIE
FOR THE QUALITY
IT WOULD TASTE ALOT BETTER
BETTER WATER
THE REPUTATION OF THE CITIES WATER SUPPLY
IT TASTES BETTER
I'D GIVE IT A TRY BUT I DON'T THINK IT WOULD NECESSARILY BE BETTER.
WELL WATER IS BETTER TASTING AND DON'T HAVE A MONTHLY WATER BILL
WELL WATER TASTES BETTER.
BETTER WATER AT A CHEAPER COST.
BUTTE WATER SUCKS!!!I WOULDN'T DRINK IT IF YOU PAID ME.
ANY IMPROVEMENT WOULD BE GOOD.
IF IT WAS BETTER AND CHEAPER, I'D PREFER WELL WATER.
I'D LIKE TO HAVE WATER THAT I COULD ACTUALLY DRINK.
WELL WATER WOULD TASTE A LOT BETTER.
I'VE HAD A WELL BEFORE, AND I THINK IT'S BETTER.
BETTER QUALITY AND COST.
IT WOULD BE BETTER WATER.
WELL WATER IS CLEANER.
WELL WATER TASTES A LOT BETTER.
WELL WATER IS MUCH BETTER.
BUTTE WATER IS SO AWFUL.
BECAUSE BUTTE IS OF POOR QUAILTY
BECAUSE OF THE BETTER QUAILITY
BECAUSE IT IS CHEAPER
RATES OF MUNICIPAL IS TOO MUCH AND SERVICE IS POOR AND I HAVE TO BUY BOTTLED WA
BETTER QUALITY AND COSTS LESS
BECAUSE IT IS BETTER AND CHEAPER
IT IS CHEAPER BUT THE INITIAL START UP IS MUCH
BECAUSE IT IS CHEAPER
LESS EXPENSIVE
IT IS CHEAPER
IT IS CHEAPER AND BETTER QUALITY
IT IS CHEAPER, LESS CHANCE OF CONTAMINATION
BECAUSE IT IS BETTER
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                  Bioeconomics, Inc: Butte Water Quality Survey
                              Responsive Management

------------ Suppose your household had a choice betw=Private well -----------
                                   (continued)

WHYSTR

BECAUSE BUTTE WATER IS LLOW IN QUALITY AND HIGH INPRICE
BECAUSE IT TASTE BETTER
BETTER TASTE AND QUALITY
BECAUSE IVE HAD A WELL BEFORE AND IT TASTED BETTER
BETTER WATER AND IT TASTES BETTER
BETTER QUALITY AND CHEAPER
ITS CLEANER AND CLEARER
ITS BETTER QUALITY AND DRINKABLE
BETTER QUALITY WATER
BETTER QUALITY AND CHEAPER
BETTER AND CHEAPER WATER
HAD A WELL BEFORE-ITS CLEANER AND ODORLESS
CHEAPER
BETTER AND MORE COST EFFICIENT
WATER IS BETTER
BUTTE WATER IS TERRIBLE
ITS BETTER
ITS BETTER WATER
LESS EXPENSIVE
IT IS BETTER WATER
THE WATER JUST TASTES BETTER
THE WATER WOULD BE BETTER
IT IS CHEAPER
BECAUSE I WILL NOT DRINK THE WATER FROM THE MUNICIPAL SUPPLY, AND THE WELL WAT
IF IT REALLY WOULD BE LESS EXPENSIVE AND WORTH THE CHANGE OVER
TO HAVE BETTER QUALITY WATER
THE QUALITY OF THE WATER WOULD BE GREATER
THE WATER QUALITY WOULD BE BETTER BUT ITS MY LANLORD WHOM WOULD MAKE THAT DECI
IT IS MORE PURE.
THE WATER FROM THE MUNICIPAL SYSTEMS IS NASTY AND THEY DO NOT SEEM TO BE DOING
ITS CHEAPER.
IT'S CLEANER AND BETTER DRINKING
QUALITY AND THE PRICE OF THE WATER
CHEAPER
FOR CLEAN WATER
COST
I DON'T LIKE DEPENDING ON SOMEONE ELSE FOR WATER.
THE WATER SYSTEM CONTINUALLY BREAKS DOWN, THE PIPES ARE OLD AND THE WATER IS B
I DON'T KNOW.
PURIFIED WATER.
I HAVE A BABY AND I DON'T TRUST THE BUTTE SYSTEM WATER.
AT LEAST THEN YOU COULD DRINK THE WATER.
IT WOULD BE BETTER WATER.
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                  Bioeconomics, Inc: Butte Water Quality Survey
                             Responsive Management

------------ Suppose your household had a choice betw=Private well ------------
                                  (continued)

WHYSTR

IF IT WOULD BE BETTER TASTING AND MORE ACCESSIBLE I WOULD WANT IT.
THE WATER QUALITY IS BETTER WITH A WELL.
IT IS CLEANER AND YOU SEND IT IN YOURSELF TO BE TESTED.
PERSONAL CONTROL OF QUALITY.
BECAUSE OF THE HIGH COST OF THE WATER COMPANY.
CANNOT DRINK BUTTE WATER
OBVIOUS
QUALITY OF BUTTE WATER
CHEAPER
SAFER
OVERCHARGE FOR BUTTE
FIRENDS WITH WELL,NOI PROBLEMS
CLEANER
CHEAPER, BETTERWATER
DON'T TRUST BUTTE WATER
BUTTE WATER IS TERRIBLE
NO WORRIES
COST
COST AND QUALITY
COST, QUALITY
CHEAPER AND BETTER QUALITY
COST
COST AND QUALITY
CHEAPER
BECAUSE I HAVE TO BUY DRINKING WATER NOW.
CLEANER WATER
LIKE WELLWATER
WATERS BETTER
CHEAPER
BETTER QUALITY OF WATER
CHEAPER
CHEAPER, BETTER QUALITY
CITY WATER IS BAD; DON'T WANT TO GIVE IT TO THEIR CHILDREN
WOULDN'T HAVE TO WORRY ABOUT THE RATES
BETTER WATER
CHEAPER AND BETTER
CONCERNED ABOUT WATER QUALITY
HAVEN'T DRANK CITY WATER FOR YEARS
BETTER TASTING WATER
YOU CAN MONITOR YOUR OWN WELLS
IF THE QUALITY OF H2O WAS BETTER
BETTER QUALITY
BETTER QUALITY, LOWER PRICE
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------------ Suppose your household had a choice betw=Private well -----------
                                   (continued)

WHYSTR

PRIVATE WELL WOULD NOT HAVE THE ACID MINE RUNOFF GOING INTO IT THEREFORE MUCH
CAUSE WATER PRICES ARE HEAD4D UP
DON'T KNOW


-------- Suppose your household had a choice betw=Municipal water syst -------

WHYSTR

NOT HAD VERY MANY PROBLEMS AND DOUBT WELLS COULD BE DRILLED IN HER AREA
HAVE A WATER FILTER
BECAUSE THE AGENCIES CHECK THE WATER
DOES NOT DRINK THE WATER ANYWAY AND IT WORKS FINE FOR EVERYTHING ELSE
NEVER FOUND ANY PROBLEMS
THEY HAVE IMPROVED THE WATER QUALITY
BECAUSE SHE IS SO OLD AND GET WELL WATER FROM THE NEIGHBORS
BECAUSE BUY BOTTLED WATER ANYWAY
GOOD WATER AND SEEMS CLEAN ENOUGH
TOO OLD TO CHANGE
EASIER
COMES FROM THE BIG HOLE RIVER
CITY WATER'S OK
BECAUSE OF UNDERGROUND MINES AND COULD CONTAIN MINERALS, ETC.
UPKEEP AND PROBLEMS
CONVENIENCE, I LIVE IN THE MIDDLE OF TOWN
BAD EXPERIENCE WITH WELL WATER IN THE PAST
WELLS ARE TOO EXPENSIVE INITIALLY
THE NEW SYSTEM IS GOOD AND WELLS ARE TOO EXPENSIVE
WATER IN THE WELLS IN BUTTE IS BAD
SATISFIED
IT WOULD BE TOO HARD TO DIG A WELL WHERE WE LIVE.
NO REASON.
THE WATER IS FINE.
I WORK FOR THE WATER COMPANY.
WE USE THE BUTTE WATER NOW, SO WE'LL STICK WITH IT.
IT'S ALREADY HOOKED UP; WHY BOTHER CHANGING?
I'M SATISFIED WITH THE PRESENT SYSTEM.
DRANK IT ALL HIS LIFE
DUE TO AGE
NEW SYSTEM IN BUTTE
BECAUSE I HAVE TOURED THEIR PLANTS AND HAVE SEEN THEIR FILTER SYSTEM.
THE WAY THE WORLD IS GOING, WELLS CAN BECOME CONTAMINATED VERY EASILY AND YOU
I DON'T WANT TO HAVE TO MESS AROUND WITH A WELL; I HAVE HAD ONE IN THE PAST AN
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                    Bioeconomics, Inc: Butte Water Quality Survey
                                Responsive Management

-------- Suppose your household had a choice betw=Municipal water syst --------
                                     (continued)

WHYSTR

I DON'T BELIEVE THE WELL WOULD BE CHEAPER.
PEOPLE HAVE SO MANY PROBLEMS WITH THEIR WELLS.
I AM AFRAID OF WHAT IS IN THE GROUND WATER.
BECAUSE I HAVE HAD LITTLE EXPERIENCE WITH WELLS AND I KNOW THAT THEY CAN GET CC
BECAUSE IF SOMETHING HAPPENED TO ANY OF THE PIPING, I WOULD NOT HAVE TO DO THE
THEY HAVE PUT
IT WOULD NOT BE WIRTHWHILE FOR US TO MAKE THE SWITCH
A WELL JUST IS NOT VERY PRACTICAL RIGHT NOW
WE CANNOT DIG A WELL IN THE CITY LIMITS
TOO MUCH OF AN IMMEDIATE EXPENSE TO PUT IN A WELL
I WOULD NOT DIG A WELL HERE
WE USUALLY HAVE BOTTLED WATER ANYWAY
IT IS EASIER
THE QUESTION IS ABSURD, YOU CAN'T PUT A WELL IN THIS AREA THAT WOULD PROVIDE A
WELLS ARE NOT ALLOWED IN THIS AREA THE QUESTION IS UNANSWERABLE
THEY HAVE REPAIRED EVERYTHING
WELLS ARE TOO MUCH TROUBLE TO MAINTAIN.
WELL WOULDN'T BE ANY BETTER.
I DON'T WANT TO TRY ANYTHING NEW; THERE'S NO NEED TO CHANGE.
THE WELL WOULD BE MORE EXPENSIVE.
WELL WATER COULD BE CONTAMINATED JUST AS EASILY
I CAN'T AFFORD ANYTHING ELSE.
IT IS IMPOSSIBLE TO HAVE A WELL IN THIS AREA!!!
I HAVEN'T HAD ANY PROBLEMS.
IT'S CLEANED UP NOW.
BECASUE IT IS CONVEINIENT
I'M HAPPY WITH IT
BECAUSE I LIVE IN BUTTE, WHY SHOULD I CHANGE
BECAUSE A WELL  IS TOO EXPENSIVE IN THE SHORT RUN
BECAUSE I LIVE IN LOW INCOME HOUSING AND HAVE NO CHOICE
BECAUSE WE ARE ON A SMALL LOT, A 30 FT LOT, NO  PLACE TO PUT A WELL
BECAUSE WE PAY TAXES FOR THE WATER
BECAUSE OF THE LOCATION, SMALL LOT AND CLOSE TO THE MINES
TOO OLD TO CHANGE
I AM SATISFIED WITH THE WATER
IM SATISFIED WITH WHAT I HAVE
WELLS GET CONTAMINATED TOO EASILY
WELLS ARE TOO MUCH TROUBLE
THE SEWER PROBS FROM WELLS
HAS NO PROBLEM WITH IT RIGHT NOW
THEY TAKE CARE OF THAT WATER-CHECK ON IT ALOT
DOESNT KNOW ANYTHING ABOUT WELL WATER
NOTHING WRONG WITH THE BUTTE WATER SYSTEM
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                    Bioeconomics, Inc: Butte Water Quality Survey
                                Responsive Management

-------- Suppose your household had a choice betw=Municipal water syst -------
                                     (continued)

WHYSTR

NOTHING'WRONG WITH IT-SHES SATISFIED WITH NO HEALTH CONCERNS
DOESNT KNOW
I LIVE UP TOWN THIS QUESTION DOES NOT APPLY BECAUSE I HAVE NO CHOICE.
OUR LOCATION PREVENTS US FROM USING A PRIVATE WELL.
WE WOULD NOT WANT TO GO THROUGH THE HASSLE OF SUCH A CHANGE
I AM PERFECTLY SATISFIED WITH THE BUTTE SYSTEM.
IT HAS NOT KILLED ME YET AND I ALWAYS DRINK THE TAP WATER.
I ALWAYS BUY MY WATER BOTTLED
IT IS CONVENIENT AND THEY JUST FIXED EVERYTHING.
THE WATER IS SUPPLIED BY THE APARTMENT OWNERS AND I HAVE ALWAYS BOUGHT MY DRIN
THE BUTTE SYSTEM IS NOT THAT BAD.
I HAVE NEVER HAD ANY PROBLEMS WITH THE MUNICIPAL WATER SYSTEM.
I FEEL IT WOULD BE SAFER IN THE LONG RUN.
ITS LOCAL AND A WELL WOULD BE A LOT MORE TROUBLE.
I AM ON A FIXED INCOME AND CANNOT AFFORD A WELL; IT IS OK THE WAY IT IS.
IT IS SIMPLER TO USE THE TOWN WATER THAN A WELL; I'VE USED A WELL BEFORE ON A
I DON'T WANT TO MESS UP SOMETHING THAT IS NOT A PROBLEM.
I DON'T HAVE ANY COMPLAINTS WITH IT.
HAD NO PROBLEMS
KNOW WHAT IT IS
NOTHING WRONG WITH IT

USED TO IT
BETTER
GOT USED TO IT
WITH IT FOR SO LONG
SATISFIED AND NO APPARENT PROBLEM
I DON'T THINK WELLS ARE THAT GOOD BECAUSE OF SEEPAGE, COST IS NOT THAT MUCH LE
IT'S JUST COMMON SENSE, WELLS JUST WON'T WORK.
IT'S HERE AND AVAILABLE NOW
LESS HASSLES
SATISFIED WITH BUTTE WATER
NOT SURE
THERE'S NO ALTERNATIVE
CAN'T HAVE PRIVATE WELL AT THEIR HOUSE-WOULD BE CONTAMINATED
MORE RELIABLE
WE LIVE UPTOWN AND WE'RE OPPOSED TO MORE WELLDRILLING IN OUR AREA
NOT SURE
GETTING TOO OLD TO GET THEIR OWN WATER AND ARE RIGHT OT\VER THE MINE
HAD PROBLEMS WITH WELLWATER IN THE PAST
AT COST IT IS A LOT CHEAPER, SINCE THE NEW SYUSTEM HE IS VERY CONFIDENT
THEY KNOW MORE THEN SOMEONE WITH WELL WATER
IT'S EASY
```

```
              Bioeconomics, Inc: Butte Water Quality Survey
                          Responsive Management

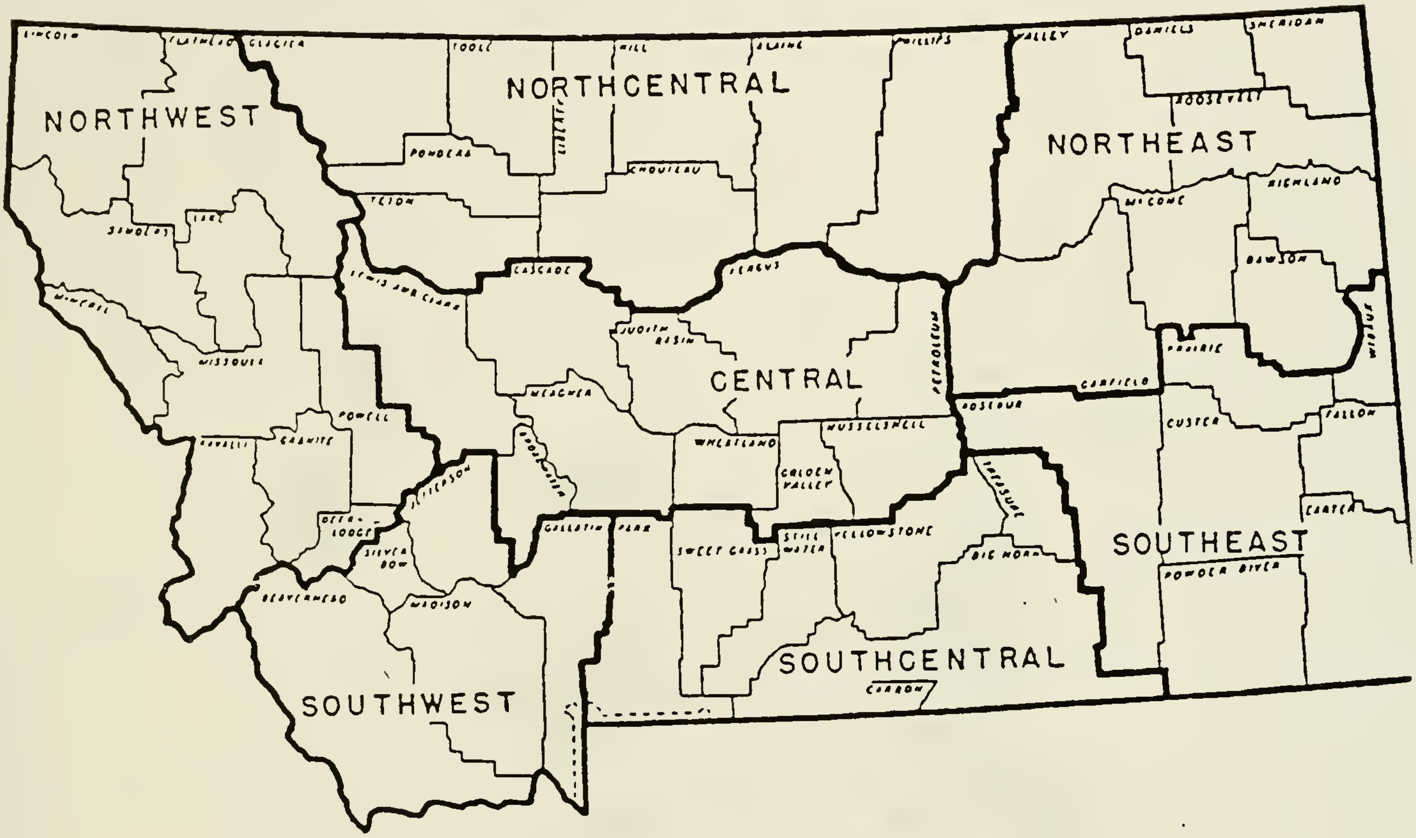
-------- Suppose your household had a choice betw=Municipal water syst --------
                               (continued)

 WHYSTR

 THE OTHER WOULD BE TOO "IFY"
 BECAUSE BE SHE LIVES IN A MINE SIGHT, BUT WOULD CONT. TO DRINK BOTTLED WATER
 BECAUSE OF LOCATION ON A HILL
```

# Appendix C: Maps of Montana Agricultural Statistics Service Districts and SCS Climatic Zones

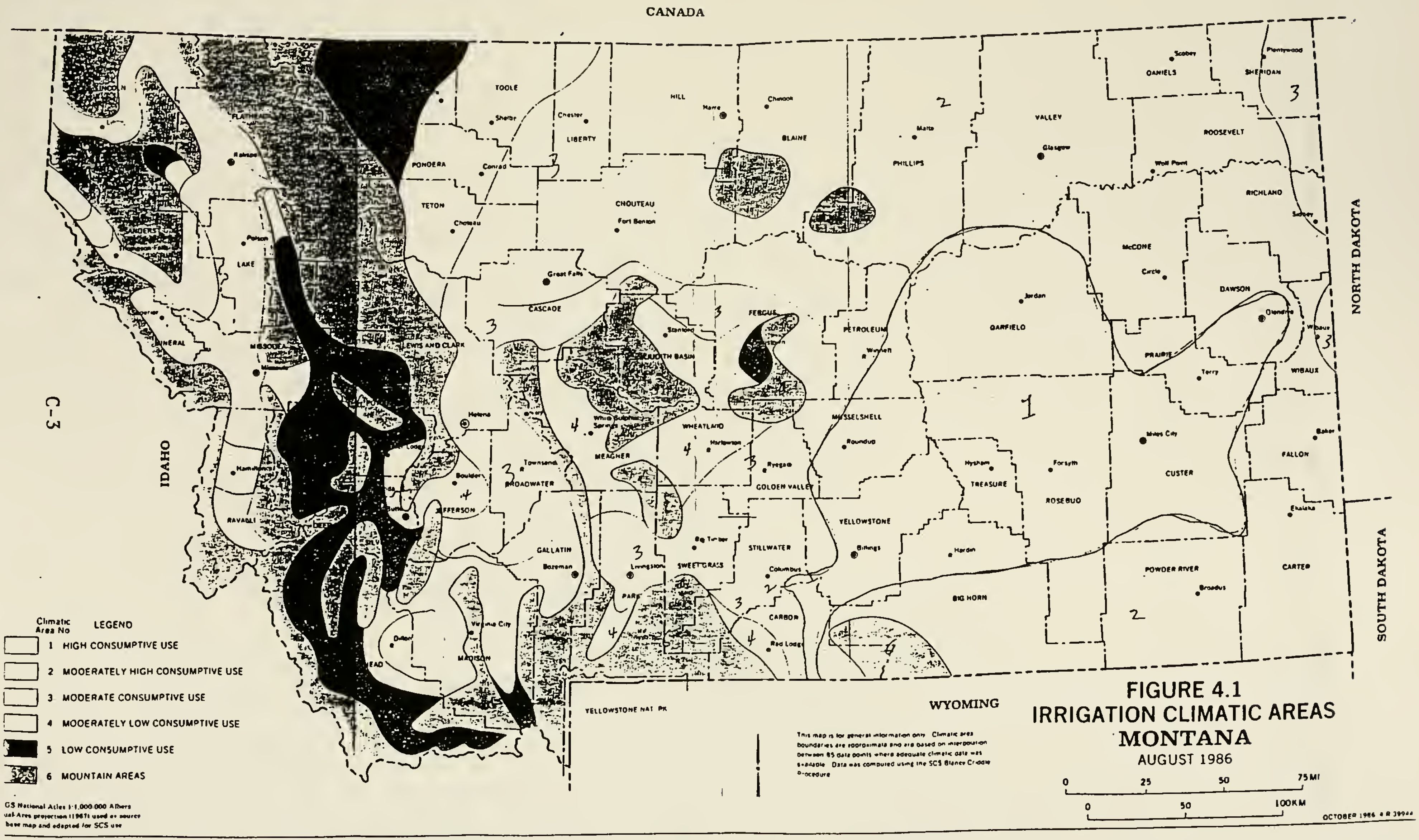
## MONTANA CROP REPORTING DISTRICTS



Montana Agricultural Statistics Service, 1992.
"Montana Agricultural Statistics 1992: County Statistics 1990-1991," Helena, MT.

U S DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE



# FIGURE 4.1
# IRRIGATION CLIMATIC AREAS
# MONTANA
AUGUST 1986

This map is for general information only. Climatic area boundaries are approximate and are based on interpolation between 85 data points where adequate climatic data was available. Data was computed using the SCS Blaney Criddle Procedure

GS National Atlas 1:1,000,000 Albers ual-Area projection (1967) used as source base map and adapted for SCS use

OCTOBER 1986 4 R 39944

## Appendix D.1: Montana Water Quality Survey, Questions J-1 to J-5 (Desvousges 1995b)

FOR OFFICE
USE ONLY

IF THE RESPONDENT IS CURRENTLY USING A WELL AT THIS ADDRESS, SKIP TO QUESTION #J-5.

Now that I know some specifics about measures you have taken to improve your water quality, I would like to ask you a few questions about the use of private wells in this area.

**J-1.** Has your household ever used a well at this address? ☐

a. yes
b. no .................................. SKIP TO QUESTION #J-4

**J-2.** In what year did it stop using this well? ☐

a. ___________ year
b. DON'T KNOW

**J-3.** Here is a list of possible reasons why people stop using their well. Please tell us why your household stopped using its well. ☐

SHOW CARD AND READ LIST. CIRCLE ALL THAT APPLY.

a. water was unsafe for drinking or food preparation .........GO TO QUESTION #J-3A
b. health concerns
c. taste of water
d. water was discolored/dirty (sand, silt, wood)
e. high mineral content of water
f. advised to stop using the well
g. required to be on the public water system
h. public water system is more convenient
i. well is too expensive
j. didn't like the hassle of the pump/maintenance
k. other, please specify: ____________________________________________
l. DON'T KNOW

IF CHOICE "A" IS NOT SELECTED SKIP TO QUESTION #J-5.

**J-3a.** What made the water unsafe for drinking or food preparation? ☐

______________________________________________________________

______________________________________________________________

SKIP TO QUESTION #J-5.

FOR OFFICE USE ONLY

**J-4.** Here is a list of possible reasons for not using a well. What are the main reasons your household decided not to use a well at this address?

SHOW CARD AND READ LIST. CIRCLE ALL THAT APPLY.

a. water is unsafe for drinking or food preparation ............ GO TO QUESTION #J-4A
b. health concerns
c. water is discolored/dirty(sand, silt, wood)
d. taste of water
e. there is a moratorium on well drilling
f. it is too expensive to drill a well
g. required to be on the public water system
h. conditions are not right for a well (will not produce sufficient water)
i. a well is not an option for me because I rent
j. never considered putting in a well
k. other, please specify: ____________________
l. DON'T KNOW

IF CHOICE "A" IS NOT SELECTED SKIP TO QUESTION #J-5.

**J-4a.** What makes the water unsafe for drinking or food preparation?

____________________

____________________

**J-5.** Suppose that your household had a choice between a well and the public water supply. If the quality of water was equally good from both sources and **all other factors**, including costs and taste, **were the same**, would your household rather use a well or the public water supply?

READ LIST. CIRCLE ONLY ONE.

a. a well
b. the public water system
c. no preference
d. depends on: ____________________
e. DON'T KNOW

## Appendix D.2: Memo from KEM, 14 February, 1995, MT-AB: Damage Methodology

14-Feb-95
RE:
[illegible] –

MT - AB: Damage Methodology

Attached is the long-waited damage methodology "memo" for the AB survey.

I have tried very hard to make it complete, but if I have missed anything please let me know. I have made recommendations when I feel strongly about something. That's fine for you to disagree. You need to be comfortable with what we're doing because you have to testify. However, there are a lot of issues that need to be decided, and I don't know how to make a good decision. I'm hoping that you can shed some light on some of these things.

I would like for you to review this memo and respond either in writing or we can sit down and talk about it. After we have made decisions among us, I would like to get input from our peer reviewers. (We'll set up a conference call to avoid putting stuff in writing.) Although I would like to hear from you this week, it is more important that you really think about this and make decisions that you're happy with rather than just responding off the top of your head. I would like all these decisions to be in place so that when the data get here, we're ready to roll.

Thanks –

K

cc: Sharon, Melissa

Possible Reorganization –

1. What are AB's?
2. How can be used to estimate potential damages?
3. What data evaluations will be performed.
4. Who's will count in the estimation?

Here are some reactions to your memo – I think it has a lot of good ideas. We need to be sure that we are all comfortable with the analysis. I think this moves us in the right direction.

should I, II + NR bias be combined + discussed as one issue?

14-Feb-95
KEM

If we had enough people who have wells, we could ~~pa~~ develop a prediction model that could tell us which ~~[illegible]~~ factors determine people with wells.

## Montana - AB:
## Determining Damages

Seems like we have a choice of being liberal & using all stated answers to J-5 or a subsample.

These questions do not indicate that people would like a well. They indicate they had one.

### I. Who Counts?

- Only households over the contaminated portion of the aquifer.
    1. They must have a well
    2. Or they must indicate that they would like a well but the groundwater is contaminated. (Questions J1 - J4)

*Query: how will we reconcile the response of J1 - J4 with the response to J5? Because J5 is a hypothetical question, recommend that responses to J1 - J4 be the deciding factor.*

There is not a reconciliation issue – this is the issue of using the hypothetical answer or the information.

- Survey results will be extrapolated to the population for the number of affected households (see "sampling weights" below.)

### II. Sampling Weights -

what does this mean?

- All households will have the same weight in terms of AB costs. Thus, we will not need to account for any weights when computing AB costs.

with reliable data?

Give e.g.

- However, we will use sampling weights to extrapolate from the sample to the population for the number of households that count.

Give e.g.

what about distinguishing between control sample + potentially affected sample? do we not have a census of the latter group? if so, then do we have weights at all? only NR adjustment

### III. Computing Damages[1]

what about both?

- For households with a well, damages will be the present value of averting behavior (AB) costs. (This is defined below.)

over what time period

- For households without a well, damages for the past and the future will be calculated differently.
    1. For the past, damages will be the present value of AB costs and municipal water bills minus the present value of costs for installing and operating a well, which will be annualized.[2]

1) only those with well?
2) CB answers
3) everyone counts

---

[1] Because we anticipate a relatively small number of households will count, we anticipate very low damage estimates. ARCO may ask us for alternative scenarios that might be viewed as more credible by the State. Is there any "intermediate" case that might make sense? We should give some thought to these alternative scenarios. [SKS suggests using responses to J-5 as an alternative scenario, which is a good idea.]

[2] The AB costs and municipal water costs will be based on survey results. The costs of installing and operating a well will be determined outside of the survey. This information has been requested from Bill Duffy. → States? should we ~~[illegible]~~ get directly from someone?

2. Future damages are contingent on the completion of the new water system. When the new water system is in place and deemed trustworthy, most AB behaviors will cease. *When that point in time occurs, should we then assume that folks would switch over to the PWS rather than continue to take AB for the contaminated groundwater?* If so, then the only portion of damages that should be counted into the future will be the cost difference in having a well versus municipal water bills.

yes

give it a yr or 2? stop it in 1995?

IV. Average annual AB cost per household

vague.

- Recommend that we compute AB costs based on most households in the sample, not just those that count.
    1. Only anticipate a very small number that count. If we use only this small number when computing AB costs, our results could be biased. We will improve the accuracy of our estimates by expanding the sample size.
    2. We anticipate that households that count and those that don't will have very similar AB's. *(When we get the data, we need to verify this.)* If this condition holds, then including more households in the calculation of costs should not bias our results.
    3. The current households are "proxies" for the households that may have moved away. Why would there be any difference in letting existing households that don't' count proxy for households that count?

households who have most reliable data? who might these be? how will we determine -

- Recommend that we compute AB on a household basis, not an activity basis
    1. By computing AB on a household basis, we account for differences in water use, family size, and whether any one behavior is combined with others. To measure at the household level, thus seems more "pure" because households are the unit of analysis.
    2. Computing AB on a behavior basis would seem inappropriate. A family buys bottled water, but they may take other averting actions. Thus, by aggregating by activity, we would treat equally AB costs for one family that might represent 10 percent of their AB costs with AB costs for another family that might represent 90 percent of their costs. How would this be reconciled? Seems like it would call for more difficult/complex analysis.

- Recommend that we base AB costs only on 1994 costs.
    1. Minimizes problems with recall bias
    2. Probably represents a worst case cost (because AB behaviors have increased over time).
    3. We will not capture the trade-off of activities over time, but 1994 behavior is more consistent with long-term nature of groundwater injury.

    4. But if filters are more prevalent in 1994, what will we do about that missing data (see note below about why filters should not be included in calculating AB costs)

- Recommend that we not use filter costs or boiling costs when compiling AB costs.
    1. The filters used by Butte households will not filter out heavy metals.
    2. Heavy metal filters are not practical at the household level and probably very (prohibitively) expensive.
    3. By including the AB costs associated with these filters, we would be underestimating damages because heavy metal filters are much more expensive.
    4. Boiling is not effective in removing heavy metals.
    5. However, we cannot merely exclude these costs, particularly if the household uses several AB measures. That would underestimate damages.
    6. Should we compile AB costs for households that do not boil and do not filter? *Recommend that we look first at the data to see how many households have filters or boil. Then, we look back to see what they did prior to having the filter installed. If they hauled or bought bottled water, we then project that behavior for 1994. If they have "always" had a filter or have "always" boiled, then we do not include that household in the average annual estimate.*

why do we suppose critics that it doesn't work? doesn't it have to be effective? thought it would be effective?

- What are we going to do about jointness?
    1. Jointness is an important consideration when computing AB costs. To not account for jointness would open us up to criticism.
    2. We have designed our questionnaire to explicitly identify jointness.
    3. There are two components of jointness relevant to our analysis: joint costs (including time costs) and joint preferences. Joint costs would include travel costs incurred when buying bottled water on a normal grocery trip. Joint preferences would include buying bottled water for both the taste and the concerns about the PWS.
    4. *Recommend that we account for joint costs, but not joint preferences, in our compilation of AB costs. We can account for joint costs objectively and mechanically. Accounting for joint preferences is much more subjective and an easier target for criticism.*
    5. Then we could estimate joint preferences as a ballpark percentage and legitimately claim that our damage estimates are generous because they would be X - Y percent lower if we had excluded joint preferences.

why not ignore as a worst case!

? ad hoc? costs what % of trip to buy bottled water is allocated?

- Under what conditions will we employ a regression-based approach, rather than simply calculating an average AB cost?
    1. For our specific application, which is better? *[Need to get **Bill's** preference and input from peer reviewers. Get them to identify the conditions under which we should do a simple average and the conditions under which we should do a regression-based approach.]*

not defined — why use? what would you gain? what do you lose? what is valid data?

if you have to get an average with data, you can run a regression —

If we think this is better, do you think ARCO wouldn't agree?

2. We will need to evaluate our data early to determine if any of these conditions hold. This evaluation will be part of our data analysis plan.
3. The regression-based approach **may** require more time or money. If we are running short on either of these commodities, can we employ a simple average approach without harming our case?

V. Opportunity Cost of Time

- Opportunity cost of time is part of AB costs.
- Opportunity cost of time will be valued at 1/3 the hourly "wage" rate.

why would this be same as recreation?

sensitivity analysis factor?

- The questionnaire is designed to allow us to calculate hourly wage rates a few different ways because the respondents may have refused to answer certain questions. The following "hierarchy " will be ~~utilized~~. used :
  1. If the respondent has replied to the household income question and the occupation question, then household income will be allocated among the heads of household (HOH) based on the proportion of combined wage rates from occupations.[3] Then, the "true" hourly wage will be computed for the more "expensive" HOH based on hours worked and proportion of household income. All opportunity costs of time will be assigned to the more "expensive" HOH.
  2. If no occupation is given but household income is supplied, then compute the average hourly wage for the household as a whole based on the number of hours worked.
  3. If no household income is supplied but the occupation is supplied, then use the BLS wage rates for that occupation.
  4. The last resort is to use the average wage across Montana.

SW? Butte?

VI. The number of years for damages

- This factor will be determined outside the survey data.
  1. The years of AB experienced in Butte is a function of the poor quality of the PWS, not the contaminated aquifer.
  2. Legal reasoning will determine when damages start and stop.

- ARCO should make this decision. *[Bill, please put this on your list to discuss with ARCO.]*
  1. When will damages begin?
  2. Should damages extend into perpetuity? ARCO has no plan to restore the aquifer, and natural recovery of the aquifer will take a ~~very, very~~ long time.

Good!

---

[3] We have obtained from BLS a detailed occupation list and accompanying wage rates for Montana. For example, if the wage rate for HOH A is \$10 and the wage rate for HOH B is \$20, then 2/3 of the household income will be attributed to HOH B [(20)/(20 + 10) = 2/3].

Sensitivity Analysis? what type? ~~[illegible]~~ Monte Carlo? other? which factors? who? ~~[illegible]~~? Opp costs? others?

3. At some future date, however, future damages will be calculated differently (see computing damages above). Can ARCO identify any factual basis for choosing that date?

VII. Other Issues Related to Overall Analysis
(to be addressed in our "forthcoming" data analysis plan)

should be moved up

- Data "~~Cleaning~~"
  1. What sort of decisions can we make about "valid" or "reliable" data based on the interviewer evaluation forms?
  2. What sort of internal consistency checks should we undertake before using data?
- What sort of analysis should we employ to address non-response bias?
- What role will the data from the control group play in our analysis?

Heckman selection model based on short interview data?

Data Evaluation

Sharon should have some thoughts here too –

- Do they have complete data?
- Are the reported AB costs internally consistent? e.g. are costs consistent with qty & time period? are relative costs of behaviors what you would expect? What do interviewers say about quality of interview? ~~[illegible]~~ What about age or education levels of respondent? Would these tell us anything?

~~[illegible]~~ were AB's consistent in terms of types? relative frequency of occurrence? costs?

does this suggest that AB costs exist primarily because PWS sucks?

## Appendix D.3: Memo from Sharom Snow to William H. Desvousges, May 10, 1995.

## William H. Desvousges

From: Sharon Snow
To: William H. Desvousges
Subject: Issues for tomorrows presentation
Date: Wednesday, May 10, 1995 3:52PM

Bill-
I have taken a look at the three issues which warranted further analysis per our discussed yesterday: well costs, who counts, and discount rates.

Well Costs:
I have taken the average of the ten domestic well found in the study and comparison areas. The mean is 53 feet and the standard deviation is 12 feet. I have used a low number of 41 feet and a high of 65 feet as part of the analysis. This results in the low and high numbers going in the Monte Carlo to be 39.32 and 138.44 (the previous numbers were 43.44 and 134.19 respectively) As you would guess this makes practically no difference in our damage numbers, with the change being less than a 1000 dollars. I just wanted to make sure you were confortable with this methodology.

Who counts:
I have investigated who in the group of people who stated that they prefer a well (n=85) also stated that they didnt currently have a well because it costs too much. These are 26 people. If we didnt allow those people to count in the high range of households the numbers of affected households in the monte carlo would range from 24 to 77. I developed a second monte carlo using these numbers. The resulting damage numbers ranged from 3.1 to 3.6 million (compared with 3.9 to 4.5 million when the range was from 24-102.)
One thing that also had to be addressed is how change who counts changes the high end of our averting behavior costs. Remember the high end was an average across the 102 households. The average for the 77 is $53 lower. This results in damage numbers further changing to 3.0 to 3.5 million.

Again, this can be in our pockets if they start to have alot of problems with the 102 number. Are you comfortable with this? Do you want it to a scenario in the presentation or just use it if necessary?

Discount rates:
The use of the 3.8 discount rate changes our original damage estimate range from 3.9 to 4.5 million to a range from 4.1 to 4.8 million.

I would be happy to discuss any of these issues with you if I havent been clear. I will have a new set of tables for you in the morning that have all the numbers you will need.

Sharon

**Potential Damages (1994$, present value to infinity)**

| | |
|---|---|
| Averting Behaviors Stop in 1995 | |
| Low | $800,254 |
| Mean | $1,912,300 |
| High | $3,209,181 |
| Averting Behaviors Stop in 2005 | |
| Low | $912,815 |
| Mean | $2,085,333 |
| High | $3,453,376 |

Our "Best" case!

Rich will love it!

## Appendix D.4: Data on Percent of Households on Individual Wells by Community.

AB-1005

|  |  | Total | Public or Private System | Individual Well Drilled | Individual Well Dug | Units w/ Other Source |  |
|---|---|---|---|---|---|---|---|
| sarokee CDP | 00175 | 476 | 429 | 41 | 0 | 6 | 8.61% |
| berton town | 00700 | 143 | 134 | 9 | 0 | 0 | 6.29% |
| Anaconda-Deer Lodge County | 01675 | 4830 | 3480 | 1160 | 92 | 98 | 25.92% |
| Arlee CDP | 02425 | 208 | 41 | 152 | 7 | 8 | 76.44% |
| Ashland CDP | 02800 | 149 | 106 | 43 | 0 | 0 | 28.86% |
| Bainville town | 03400 | 96 | 96 | 0 | 0 | 0 | 0.00% |
| Baker city | 03475 | 966 | 966 | 0 | 0 | 0 | 0.00% |
| Bearcreek town | 04300 | 25 | 25 | 0 | 0 | 0 | 0.00% |
| Belgrade city | 04975 | 1290 | 1244 | 46 | 0 | 0 | 3.57% |
| Belt city | 05275 | 291 | 288 | 3 | 0 | 0 | 1.03% |
| Big Sandy town | 06250 | 372 | 370 | 2 | 0 | 0 | 0.54% |
| Big Timber city | 06475 | 771 | 768 | 3 | 0 | 0 | 0.39% |
| Billings city | 06550 | 35964 | 35647 | 284 | 15 | 18 | 0.83% |
| Bonner-West Riverside CDP | 08462 | 720 | 172 | 511 | 29 | 8 | 75.00% |
| Boulder town | 08575 | 521 | 519 | 2 | 0 | 0 | 0.38% |
| Bozeman city | 08950 | 9117 | 8774 | 320 | 16 | 7 | 3.69% |
| Bridger town | 09475 | 342 | 334 | 6 | 2 | 0 | 2.34% |
| Broadus town | 09700 | 287 | 281 | 6 | 0 | 0 | 2.09% |
| Broadview town | 09775 | 65 | 63 | 2 | 0 | 0 | 3.08% |
| Brockton town | 10000 | 103 | 103 | 0 | 0 | 0 | 0.00% |
| Browning town | 10375 | 421 | 421 | 0 | 0 | 0 | 0.00% |
| Busby CDP | 11200 | 182 | 135 | 40 | 7 | 0 | 25.82% |
| Butte-Silver Bow (remainder) | 11397 | 15174 | 13883 | 1159 | 79 | 53 | 8.16% |
| Cascade town | 12775 | 343 | 340 | 3 | 0 | 0 | 0.87% |
| arlo CDP | 13900 | 161 | 134 | 27 | 0 | 0 | 16.77% |
| Chester town | 14200 | 470 | 470 | 0 | 0 | 0 | 0.00% |
| Chinook city | 14575 | 794 | 791 | 0 | 0 | 3 | 0.00% |
| Choteau city | 14650 | 858 | 658 | 190 | 6 | 4 | 22.84% |
| Circle town | 14950 | 396 | 394 | 2 | 0 | 0 | 0.51% |
| Clyde Park town | 15550 | 139 | 131 | 3 | 3 | 2 | 4.32% |
| Colstrip CDP | 16525 | 1192 | 1186 | 6 | 0 | 0 | 0.50% |
| Columbia Falls city | 16600 | 1204 | 1167 | 37 | 0 | 0 | 3.07% |
| Columbus town | 16825 | 681 | 681 | 0 | 0 | 0 | 0.00% |
| Conrad city | 17275 | 1267 | 1267 | 0 | 0 | 0 | 0.00% |
| Crow Agency CDP | 18250 | 327 | 301 | 16 | 0 | 10 | 4.89% |
| Culbertson town | 18475 | 361 | 361 | 0 | 0 | 0 | 0.00% |
| Cut Bank city | 18775 | 1532 | 1532 | 0 | 0 | 0 | 0.00% |
| Darby town | 19300 | 293 | 270 | 15 | 4 | 4 | 6.48% |
| Deer Lodge city | 19825 | 1636 | 1612 | 20 | 0 | 4 | 1.22% |
| Denton town | 20425 | 169 | 169 | 0 | 0 | 0 | 0.00% |
| Dillon city | 20800 | 1804 | 1652 | 89 | 0 | 63 | 4.93% |
| Dodson town | 21025 | 75 | 75 | 0 | 0 | 0 | 0.00% |
| Drummond town | 21850 | 154 | 20 | 121 | 9 | 4 | 84.42% |
| Dutton town | 22600 | 171 | 171 | 0 | 0 | 0 | 0.00% |
| East Glacier Park Village CDP | 22985 | 212 | 212 | 0 | 0 | 0 | 0.00% |
| East Helena town | 23125 | 644 | 611 | 29 | 0 | 4 | 4.50% |
| Ekalaka town | 23650 | 291 | 291 | 0 | 0 | 0 | 0.00% |
| is town | 24475 | 397 | 378 | 16 | 3 | 0 | 4.79% |
| Eureka town | 24850 | 480 | 468 | 5 | 4 | 3 | 1.88% |
| Evergreen CDP | 25075 | 1635 | 1389 | 227 | 19 | 0 | 15.05% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fairfield town | 25225 | 319 | 317 | 2 | 0 | 0 | 0.63% |
| Fairview city | 25300 | 441 | 386 | 37 | 18 | 0 | 12.47% |
| Finley Point CDP | 26226 | 533 | 12 | 381 | 0 | 140 | 71.48% |
| xville town | 26800 | 43 | 43 | 0 | 0 | 0 | 0.00% |
| orsyth city | 27700 | 981 | 973 | 8 | 0 | 0 | 0.82% |
| Fort Belknap CDP | 27775 | 161 | 157 | 4 | 0 | 0 | 2.48% |
| Fort Benton city | 28000 | 734 | 727 | 0 | 0 | 7 | 0.00% |
| Fort Peck town | 28450 | 243 | 106 | 0 | 9 | 128 | 3.70% |
| Frazer CDP | 29275 | 132 | 132 | 0 | 0 | 0 | 0.00% |
| Froid town | 29500 | 143 | 143 | 0 | 0 | 0 | 0.00% |
| Fromberg town | 29575 | 210 | 200 | 3 | 5 | 2 | 3.81% |
| Geraldine town | 30400 | 137 | 137 | 0 | 0 | 0 | 0.00% |
| Glasgow city | 31075 | 1744 | 1734 | 6 | 0 | 4 | 0.34% |
| Glendive city | 31450 | 2391 | 2366 | 18 | 7 | 0 | 1.05% |
| Grass Range town | 32575 | 91 | 83 | 5 | 0 | 3 | 5.49% |
| Great Falls city | 32800 | 24157 | 23989 | 143 | 17 | 8 | 0.66% |
| Hamilton city | 33775 | 1476 | 1296 | 180 | 0 | 0 | 12.20% |
| Hardin city | 34225 | 1303 | 1270 | 24 | 0 | 9 | 1.84% |
| Harlem city | 34375 | 398 | 396 | 0 | 0 | 2 | 0.00% |
| Harlowton city | 34450 | 589 | 577 | 7 | 4 | 1 | 1.87% |
| Havre city | 35050 | 4335 | 4305 | 21 | 0 | 9 | 0.48% |
| Havre North CDP | 35125 | 502 | 33 | 383 | 69 | 17 | 90.04% |
| Hays CDP | 35275 | 123 | 76 | 44 | 3 | 0 | 38.21% |
| Heart Butte CDP | 35350 | 119 | 83 | 23 | 7 | 6 | 25.21% |
| Helena city | 35600 | 10946 | 10785 | 155 | 0 | 6 | 1.42% |
| Helena Valley Northeast CDP | 35628 | 597 | 132 | 422 | 18 | 25 | 73.70% |
| elena Valley Northwest CDP | 35631 | 423 | 27 | 362 | 34 | 0 | 93.62% |
| lena Valley Southeast CDP | 35634 | 1643 | 598 | 1020 | 19 | 6 | 63.24% |
| Helena Valley West Central CDP | 35637 | 2281 | 423 | 1797 | 61 | 0 | 81.46% |
| Helena West Side CDP | 35640 | 779 | 363 | 404 | 6 | 6 | 52.63% |
| Hingham town | 36400 | 69 | 65 | 0 | 0 | 4 | 0.00% |
| Hobson town | 36700 | 119 | 2 | 35 | 64 | 18 | 83.19% |
| Hot Springs town | 37825 | 377 | 359 | 18 | 0 | 0 | 4.77% |
| Hysham town | 38350 | 180 | 180 | 0 | 0 | 0 | 0.00% |
| Ismay town | 38950 | 23 | 0 | 20 | 3 | 0 | 100.00% |
| Joliet town | 39700 | 264 | 264 | 0 | 0 | 0 | 0.00% |
| Jordan town | 39925 | 258 | 238 | 18 | 0 | 2 | 6.98% |
| Judith Gap city | 40000 | 61 | 61 | 0 | 0 | 0 | 0.00% |
| Kalispell city | 40075 | 5537 | 5461 | 63 | 0 | 13 | 1.14% |
| Kevin town | 40525 | 107 | 107 | 0 | 0 | 0 | 0.00% |
| Kicking Horse CDP | 40580 | 16 | 0 | 16 | 0 | 0 | 100.00% |
| Lame Deer CDP | 42250 | 603 | 440 | 155 | 8 | 0 | 27.03% |
| Laurel city | 42700 | 2596 | 2579 | 17 | 0 | 0 | 0.65% |
| Lavina town | 42850 | 82 | 6 | 76 | 0 | 0 | 92.68% |
| Lewistown city | 43375 | 2867 | 2822 | 31 | 14 | 0 | 1.57% |
| Libby city | 43450 | 1168 | 1130 | 15 | 23 | 0 | 3.25% |
| Lima town | 43525 | 176 | 173 | 0 | 0 | 3 | 0.00% |
| Livingston city | 43975 | 3137 | 3119 | 18 | 0 | 0 | 0.57% |
| Lockwood CDP | 44200 | 1500 | 1379 | 83 | 16 | 22 | 6.60% |
| odge Grass town | 44275 | 177 | 177 | 0 | 0 | 0 | 0.00% |
| o CDP | 44650 | 953 | 601 | 346 | 6 | 0 | 36.94% |
| Malmstrom AFB CDP | 47275 | 1496 | 1490 | 0 | 0 | 6 | 0.00% |
| Malta city | 47425 | 1144 | 1134 | 10 | 0 | 0 | 0.87% |

|  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
| Manhattan town | 47575 | 405 | 400 | 5 | 0 | 0 | 1.23% |
| Medicine Lake town | 48775 | 192 | 192 | 0 | 0 | 0 | 0.00% |
| Melstone town | 49000 | 90 | 82 | 8 | 0 | 0 | 8.89% |
| es City city | 49525 | 4006 | 3919 | 75 | 7 | 5 | 2.05% |
| ssoula city | 50200 | 18488 | 17901 | 566 | 21 | 0 | 3.18% |
| Moore town | 51550 | 94 | 88 | 1 | 4 | 1 | 5.32% |
| Muddy CDP | 52315 | 124 | 65 | 59 | 0 | 0 | 47.58% |
| Nashua town | 52900 | 221 | 221 | 0 | 0 | 0 | 0.00% |
| Neihart town | 53200 | 132 | 80 | 2 | 6 | 44 | 6.06% |
| North Browning CDP | 54510 | 485 | 458 | 27 | 0 | 0 | 5.57% |
| Opheim town | 55525 | 97 | 97 | 0 | 0 | 0 | 0.00% |
| Orchard Homes CDP | 55675 | 4339 | 2056 | 2254 | 29 | 0 | 52.62% |
| Outlook town | 56050 | 53 | 46 | 5 | 0 | 2 | 9.43% |
| Pablo CDP | 56350 | 499 | 300 | 199 | 0 | 0 | 39.88% |
| Philipsburg town | 57175 | 487 | 482 | 5 | 0 | 0 | 1.03% |
| Pinesdale town | 57700 | 93 | 75 | 18 | 0 | 0 | 19.35% |
| Plains town | 58150 | 476 | 466 | 10 | 0 | 0 | 2.10% |
| Plentywood city | 58375 | 1102 | 1091 | 11 | 0 | 0 | 1.00% |
| Plevna town | 58450 | 90 | 87 | 3 | 0 | 0 | 3.33% |
| Polson city | 58750 | 1561 | 1531 | 17 | 0 | 13 | 1.09% |
| Poplar city | 58975 | 386 | 386 | 0 | 0 | 0 | 0.00% |
| Pryor CDP | 59950 | 185 | 88 | 85 | 0 | 12 | 45.95% |
| Red Lodge city | 61525 | 1248 | 1202 | 19 | 13 | 14 | 2.56% |
| Rexford town | 62200 | 59 | 57 | 2 | 0 | 0 | 3.39% |
| Richey town | 62275 | 179 | 173 | 2 | 0 | 4 | 1.12% |
| Ronan city | 64150 | 715 | 709 | 6 | 0 | 0 | 0.84% |
| Roundup city | 64525 | 1004 | 1001 | 3 | 0 | 0 | 0.30% |
| egate town | 64975 | 130 | 94 | 36 | 0 | 0 | 27.69% |
| Saco town | 65050 | 146 | 142 | 4 | 0 | 0 | 2.74% |
| St. Ignatius town | 65275 | 342 | 319 | 23 | 0 | 0 | 6.73% |
| Scobey city | 66925 | 638 | 631 | 5 | 0 | 2 | 0.78% |
| Shelby city | 67450 | 1302 | 1302 | 0 | 0 | 0 | 0.00% |
| Sheridan town | 67600 | 338 | 293 | 45 | 0 | 0 | 13.31% |
| Sidney city | 67900 | 2363 | 2102 | 169 | 81 | 11 | 10.58% |
| South Browning CDP | 69680 | 493 | 481 | 3 | 0 | 9 | 0.61% |
| Stanford town | 70675 | 265 | 259 | 2 | 4 | 0 | 2.26% |
| Starr School CDP | 70825 | 72 | 72 | 0 | 0 | 0 | 0.00% |
| Stevensville town | 71200 | 512 | 504 | 7 | 0 | 1 | 1.37% |
| Sunburst town | 72175 | 215 | 215 | 0 | 0 | 0 | 0.00% |
| Sun Prairie CDP | 72380 | 451 | 392 | 37 | 18 | 4 | 12.20% |
| Superior town | 72625 | 388 | 374 | 11 | 2 | 1 | 3.35% |
| Terry town | 73675 | 401 | 69 | 300 | 32 | 0 | 82.79% |
| Thompson Falls city | 73825 | 582 | 582 | 0 | 0 | 0 | 0.00% |
| Three Forks town | 73975 | 549 | 523 | 21 | 5 | 0 | 4.74% |
| Townsend city | 74575 | 749 | 727 | 18 | 4 | 0 | 2.94% |
| Troy city | 75025 | 421 | 414 | 5 | 0 | 2 | 1.19% |
| Twin Bridges town | 75475 | 242 | 234 | 8 | 0 | 0 | 3.31% |
| Valier town | 76225 | 260 | 259 | 1 | 0 | 0 | 0.38% |
| Virginia City town | 77125 | 118 | 98 | 18 | 0 | 2 | 15.25% |
| Walkerville city | 77650 | 300 | 295 | 3 | 0 | 2 | 1.00% |
| stby town | 78925 | 135 | 128 | 5 | 2 | 0 | 5.19% |
| West Yellowstone town | 79525 | 687 | 365 | 319 | 3 | 0 | 46.87% |
| Whitefish city | 79825 | 2259 | 2192 | 44 | 0 | 23 | 1.95% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Whitehall town | 79900 | 502 | 500 | 2 | 0 | 0 | 0.40% |
| White Sulphur Springs city | 80050 | 514 | 496 | 12 | 0 | 6 | 2.33% |
| Wibaux town | 80350 | 313 | 306 | 7 | 0 | 0 | 2.24% |
| nifred town | 81025 | 87 | 83 | 4 | 0 | 0 | 4.60% |
| nnett town | 81100 | 111 | 101 | 2 | 0 | 8 | 1.80% |
| Wolf Point city | 81475 | 1236 | 1236 | 0 | 0 | 0 | 0.00% |
| | | | | | | | |
| | | 225014 | 207707 | 15458 | 937 | 912 | 7.29% |
| | | | | | | | |
| Cities/Towns in SouthWest Montana from Missoula to Helena to Bozeman and southwest. | | | | | | | |
| | | | | | | | |
| Alberton town | 00700 | 143 | 134 | 9 | 0 | 0 | 6.29% |
| Anaconda-Deer Lodge County | 01675 | 4830 | 3480 | 1160 | 92 | 98 | 25.92% |
| Arlee CDP | 02425 | 208 | 41 | 152 | 7 | 8 | 76.44% |
| Belgrade city | 04975 | 1290 | 1244 | 46 | 0 | 0 | 3.57% |
| Bonner-West Riverside CDP | 08462 | 720 | 172 | 511 | 29 | 8 | 75.00% |
| Boulder town | 08575 | 521 | 519 | 2 | 0 | 0 | 0.38% |
| Bozeman city | 08950 | 9117 | 8774 | 320 | 16 | 7 | 3.69% |
| Butte-Silver Bow (remainder) | 11397 | 15174 | 13883 | 1159 | 79 | 53 | 8.16% |
| Darby town | 19300 | 293 | 270 | 15 | 4 | 4 | 6.48% |
| Deer Lodge city | 19825 | 1636 | 1612 | 20 | 0 | 4 | 1.22% |
| Dillon city | 20800 | 1804 | 1652 | 89 | 0 | 63 | 4.93% |
| Drummond town | 21850 | 154 | 20 | 121 | 9 | 4 | 84.42% |
| East Helena town | 23125 | 644 | 611 | 29 | 0 | 4 | 4.50% |
| Ennis town | 24475 | 397 | 378 | 16 | 3 | 0 | 4.79% |
| Hamilton city | 33775 | 1476 | 1296 | 180 | 0 | 0 | 12.20% |
| elena city | 35600 | 10946 | 10785 | 155 | 0 | 6 | 1.42% |
| lena Valley Northeast CDP | 35628 | 597 | 132 | 422 | 18 | 25 | 73.70% |
| Helena Valley Northwest CDP | 35631 | 423 | 27 | 362 | 34 | 0 | 93.62% |
| Helena Valley Southeast CDP | 35634 | 1643 | 598 | 1020 | 19 | 6 | 63.24% |
| Helena Valley West Central CDP | 35637 | 2281 | 423 | 1797 | 61 | 0 | 81.46% |
| Helena West Side CDP | 35640 | 779 | 363 | 404 | 6 | 6 | 52.63% |
| Lima town | 43525 | 176 | 173 | 0 | 0 | 3 | 0.00% |
| Lolo CDP | 44650 | 953 | 601 | 346 | 6 | 0 | 36.94% |
| Manhattan town | 47575 | 405 | 400 | 5 | 0 | 0 | 1.23% |
| Missoula city | 50200 | 18488 | 17901 | 566 | 21 | 0 | 3.18% |
| Orchard Homes CDP | 55675 | 4339 | 2056 | 2254 | 29 | 0 | 52.62% |
| Philipsburg town | 57175 | 487 | 482 | 5 | 0 | 0 | 1.03% |
| Pinesdale town | 57700 | 93 | 75 | 18 | 0 | 0 | 19.35% |
| Sheridan town | 67600 | 338 | 293 | 45 | 0 | 0 | 13.31% |
| Stevensville town | 71200 | 512 | 504 | 7 | 0 | 1 | 1.37% |
| Three Forks town | 73975 | 549 | 523 | 21 | 5 | 0 | 4.74% |
| Townsend city | 74575 | 749 | 727 | 18 | 4 | 0 | 2.94% |
| Twin Bridges town | 75475 | 242 | 234 | 8 | 0 | 0 | 3.31% |
| Virginia City town | 77125 | 118 | 98 | 18 | 0 | 2 | 15.25% |
| Walkerville city | 77650 | 300 | 295 | 3 | 0 | 2 | 1.00% |
| West Yellowstone town | 79525 | 687 | 365 | 319 | 3 | 0 | 46.87% |
| Whitehall town | 79900 | 502 | 500 | 2 | 0 | 0 | 0.40% |
| White Sulphur Springs city | 80050 | 514 | 496 | 12 | 0 | 6 | 2.33% |
| | | | | | | | |
| | | 84528 | 72137 | 11636 | 445 | 310 | 14.29% |

## Appendix D.5: Sample Questions and Answers for Montana Water Quality Study, Desvouges (1995b).

## SAMPLE QUESTIONS AND ANSWERS FOR MONTANA WATER QUALITY STUDY

***Q:*** ***Who is sponsoring this study?***

A: Triangle Economic Research has hired Market Research Group to conduct the study. It is our policy not to reveal any details of the sponsor. We do not want to bias the results of the survey in any way.

**OR IF THAT DOESN'T SATISFY THE RESPONDENT:**

I cannot tell you who the sponsor of the study is because I have not been told. Triangle Economic Research does not want the interviewers to be able to bias your responses in the study.

**IF IT'S STILL A PROBLEM:**

I'd be happy to set up an appointment for you to talk with the supervisors of the study about this issue. [THEN YOU WILL ASK FOR A GOOD TIME TO HAVE SHARON SNOW OR MELISSA RUBY GIVE THEM A CALL].

***Q:*** ***Who is Triangle Economic Research (or What does TER do?)***

A: Triangle Economic Research conducts studies of applied and basic research across the United States. Much of this research is focused on environmental issues and choices people make.

***Q:*** ***Will the information I provide remain confidential?***

A: I cannot guarantee that your information will be confidential. However, it will only be used for the purposes of this study. You will not be placed on any mailing lists or anything of that sort.

***Q:*** ***What is the purpose/objective of this study?***

A: We are trying to learn more about how people view the quality of water in their homes and the choices they make in response to water quality problems.

***Q:*** ***What if I don't have any water quality problems, or I don't take any measures to improve my water quality?***

A: That's fine. Your interview will be very short then. We need to know how different kinds of people view water quality issues. It is important for scientific accuracy that you participate in the study.

***Q:*** ***I don't have any water quality problems, but my friend/neighbor/co-worker does. Can I give you his/her number instead?***

A: No, we would like you to take the survey, even if you don't have any water quality problems or don't take any measures to improve your water quality. It is important for us to get a good understanding of how different kinds of people view water quality issues. It is important for scientific accuracy that you participate in the study.

Q: *Why don't you call on someone else?*

A: To have an accurate study, we need to interview your household. Your participation is very important. We need to have a scientifically accurate sample of people that represents the Butte area.

Q: ***My husband/wife knows the most about water quality in our home, but he/she is out-of-town/unavailable/etc. for the next two months.***

A: If your spouse is unavailable, we would like you to take the survey. You can consult with your spouse before your interview. You can also look at any records or receipts that would help you answer our questions. It is very important that your household is represented in our survey.

Q: *What if the time I schedule my appointment for turns out to be inconvenient?*

A: You will receive a postcard in the mail confirming your appointment. On that card will be a number you can call to change your appointment if that time is inconvenient. We can reschedule your appointment for any time of the day or evening that is convenient for you.

Q: *Are you selling something? Is my name going to be put on a mailing list?*

A: No, we are not selling anything. We are conducting a scientific study on water quality issues. Your name will not be put on any mailing lists.

Q: *How did you get my number?*

A: Your phone number was based on your address. Your address was scientifically selected at random by a computer from a list of addresses in the Butte area.

Q: *How did you get my name?*

A: Your address was scientifically selected at random. We then matched your address with a list of names and telephone numbers.

Q: *Why do you want my name; what are you going to do with it?*

A: We want to be able to tell our interviewer who to ask for when they come to your home, and who to make the check out to.

Q: *Why do you need to verify my address and telephone number?*

A: We need to make sure that we send an interviewer to the correct address. The people in charge of the study have to check the accuracy of their sample. (IF ASKED TO EXPLAIN): The sample is based on addresses. The supervisors of the study need to check them to be sure the sample is correct. **(IF RESPONDENT HAS AGREED TO INTERVIEW):** We also need to make sure that we send an interviewer to the correct address.